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As the Nation's principal conservation agency, the Department works to assure that nonrenewable resources are developed and used wisely, that park and recreational resources are conserved for the future, and that renewable resources make their full contribution to the progress, prosperity, and security of the United States—now and in the future.

LIFE HISTORY OF THE SPINY DOGFISH

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ABSTRACT

The spiny dogfish, a small shark, is a costly nuisance to commercial fishermen off both coasts of the United States. Data on the species' life history were gathered from the literature and from original studies and assembled in one report as a basis for possible future management. The species reaches a maximum length of 100-124 cm. and a maximum weight of 7-10 kg. The females are slightly larger than the males. Dogfish are known to migrate in large schools and, occasionally, to travel long distances. Tagging studies suggest they move offshore in the winter and inshore in the summer. They are opportunistic feeders with a diet list that includes fishes and crustaceans. Age determinations from interpretation of spine markings indicate the dogfish are long lived with some individuals living for

20 or 30 years. The species is ovoviparous and mating takes place in the cold months. After a nearly 2-year gestation period, a female gives birth to 3-11 pups, each about 25 cm. long. Natural mortality rate apparently is low, and the species has few natural enemies. In 1944 more than 40 million pounds of spiny dogfish were landed as a source of vitamin A. Today about 2 million pounds are landed. In the United States the species has limited value as an industrial fish and even less value as a food fish. It is edible, however, and is valued as food in some European nations. Management of the spiny dogfish off North America is indicated to reduce the damage it causes to more valuable commercial fisheries.

The spiny dogfish *Squalus acanthias* L., a small shark of the family Squalidae, has been one of the most intensively studied fishes, but one in which extensive knowledge is lacking. The species is studied by college students in zoology, ichthyology, comparative anatomy, and vertebrate taxonomy and is a favorite experimental animal for physiological studies including pharmacological toxicity tests. Few comprehensive biological studies of this fish have been made, however, except for Ford's (1921) study at Plymouth, England, Templeman's (1944) study in Newfoundland, and the studies made by Bonham, Sanford, Clegg, and Bucher (1949) in the State of Washington. In general, most of the published reports represent isolated observations or extremely specific studies. As a result, we know, for example, the function of the rectal gland of the spiny dogfish (Burger

and Hess, 1960), but we do not know the wintering grounds of the species; we know the mechanism controlling movements of the spiral intestine (Sawyer, 1933), but we do not know the relationship between the groups of dogfish in any one area.

This paper is an attempt to organize and summarize the available information, to which I have added additional original data from recent studies of the spiny dogfish in the Northwest Atlantic. This report is undoubtedly incomplete, but will serve as a starting point for other studies and help the researcher who is not completely familiar with the literature to interpret future observations.

As a convenient method of handling the information, the various phases of the life history of the fish are taken up in turn. Because the species is distributed throughout the Northern Hemisphere (Bigelow and Schroeder, 1948), I have reviewed reports from both the Atlantic and Pacific Oceans. Some consideration has been given,

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as well, to the role of the spiny dogfish in the commercial fishery.

Much of the information reported here is of interest solely because it adds to man's fund of knowledge about the species; however, some of the information has more concrete implications for our commercial fishermen. This latter consideration has been aptly summed up by Bigelow and Schroeder (1948), who state:

"From a practical aspect the spiny dog in the Western Atlantic is chiefly important because it is undoubtedly more destructive to gear and interferes more with fishing operations than does any other fish—shark or teleost."

DESCRIPTION

The spiny dogfish is typically sharklike in appearance (fig. 1). In Western Atlantic waters it

grows to a length of about 50–90 cm. and weighs 3.5–4.9 kg., with a maximum of about 100 cm. and 7.3–9.8 kg. The females are slightly larger than the males (Bigelow and Schroeder, 1953). In the Pacific Ocean, off the west coast of the United States, the males reach a maximum of about 100 cm. and 3.9 kg., while the females reach a maximum of about 124 cm. and 9.8 kg. (Bonham et al., 1949).

The upper part of the fish is slate colored, sometimes tinged with brown, with irregular rows of small white spots on each side. The white spots are generally typical of younger fish and may be lacking on older individuals. A distinguishing feature of this shark is the presence of two sharp spines, one anterior to each dorsal fin, the rear spine longer than the front spine. Halstead (1959) reports that a venom gland is located on

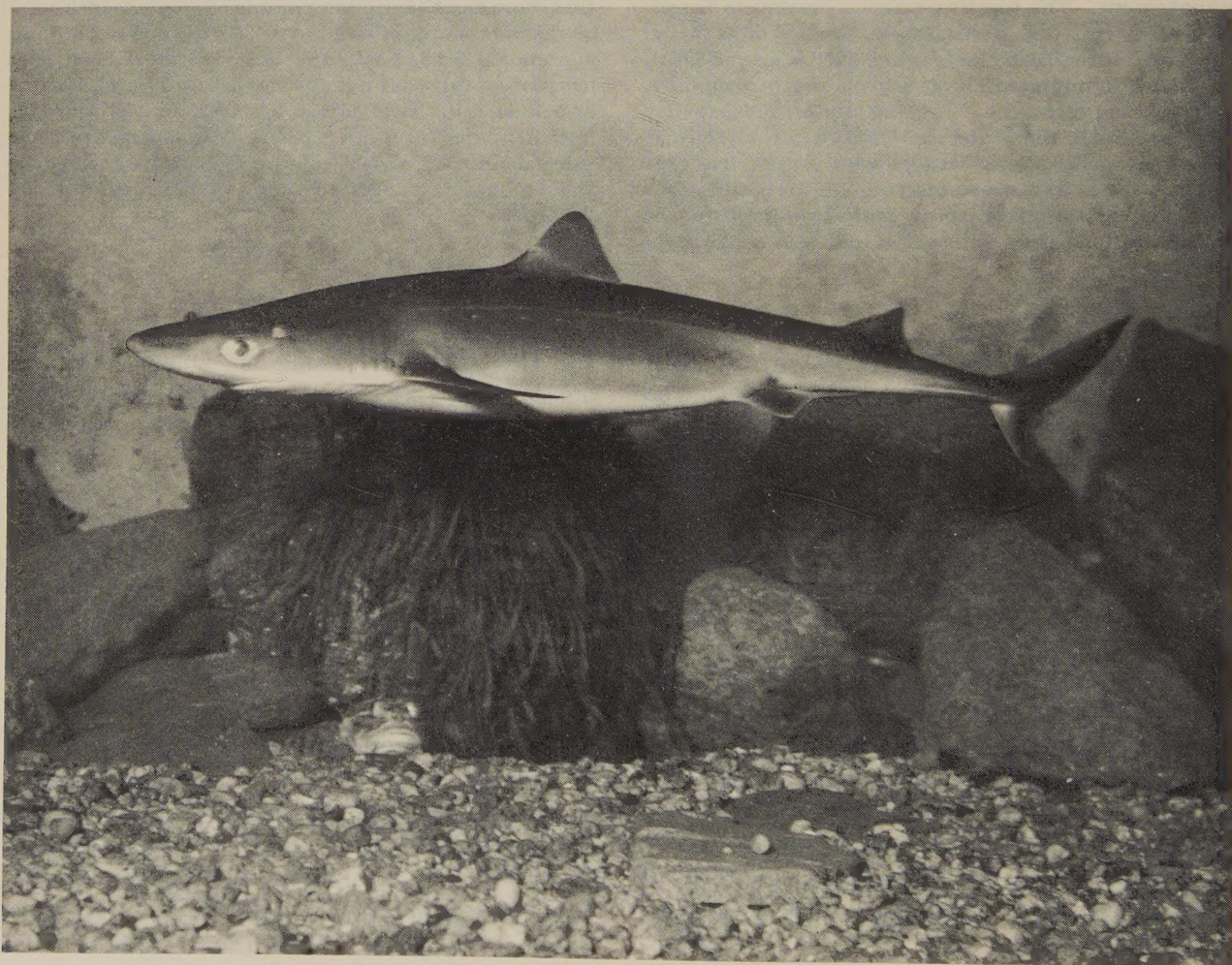


FIGURE 1.—The spiny dogfish, *Squalus acanthias*.

the upper posterior part of each spine. He cites no case histories of injuries, however. The spines presumably are used in defense and are capable of inflicting a painful wound.

Spiny dogfish frequently are confused with the smooth dogfish, *Mustelus canis* (Mitchill), a member of the family Triakidae, although examination of the two species will clearly separate them. The smooth dogfish, as the name implies, lacks the sharp dorsal spines. It is a lighter color than the spiny, although it has great ability to change color to match its surroundings. Above a white sandy bottom it usually is a translucent, pearly shade; over a dark bottom it will have a darker color. Individuals, in general, tend to be larger than spiny dogfish; smooth dogfish are 89–137 cm. long with a few attaining 152 cm. in length. Food of the smooth dogfish is mostly large Crustacea, especially lobsters and crabs, although it also eats small fish such as menhaden and tautog. It is a coastal, warm water species that ranges in the Western Atlantic from Uruguay and southern Brazil to Cape Cod. It is one of the sharks that develops a placental attachment between the embryos and the mother; thus it is truly viviparous. The smooth dogfish is of little concern to commercial fishermen.

DISTRIBUTION

Distribution of the spiny dogfish has been, until recently, somewhat obscured by the question of its specific identity. Many ichthyologists held that there were two distinct species, *S. acanthias* in the North Atlantic Ocean and *S. suckleyi* in the North Pacific Ocean. Bigelow and Schroeder (1948) noted that although it was not entirely clear how the two species were related, they had not obviously differentiated themselves specifically during the period since their ranges had become discontinuous. The prevailing opinion today is that the two populations represent but a single species, *S. acanthias*, which occurs in both the Atlantic and Pacific Oceans (American Fisheries Society, 1960). Briefly, the distribution may be expressed as both sides of the North Atlantic, chiefly in temperate and subarctic latitudes, and also on both sides of the North Pacific, in similar latitudes (fig. 2), with close allies in corresponding latitudes in the Southern Hemisphere. The species is of minor economic importance in the Southeast Atlantic, off the West Coast of Africa, but fairly important in

Mediterranean Atlantic waters.² It occurs chiefly in continental, as contrasted with oceanic, waters, anywhere between the surface and the bottom down to 165–185 meters (Bigelow and Schroeder, 1948) and has been found as deep as 290 meters (see table 1).



FIGURE 2.—Distribution of the spiny dogfish in the Northern Hemisphere.

The distribution in the Northeast Atlantic is described in detail by Bigelow and Schroeder (1948) as follows: off France, north to Ireland, Scotland, southern Scandinavia, the English Channel, and the North Sea, from there eastward to the Kattegat. The spiny dogfish rarely enters the Baltic Sea. It is plentiful around the Orkney Islands, the Faroes, and south and east of Iceland (but less to the north and west), and is found off Norway to the Murman coast. It is also generally distributed in the Mediterranean Sea and the Black Sea.

In the Northwest Atlantic the spiny dogfish is found in coastal waters from Cape Lookout, N.C., northward around Nova Scotia, along both the northern and southern shores of the Gulf of St. Lawrence, past the Strait of Belle Isle to southeast

² Food and Agriculture Organization of the United Nations. 1957. The present status of knowledge of the living resources of the marine waters of the West Coast of Africa. Fisheries Division, Biology Branch, Rome, Italy, 30 pp. [Unpublished processed report.]

Labrador (Bigelow and Schroeder, 1948). It is common northward along the coasts of Newfoundland. There is no record of its occurring along the coast north of Hamilton Inlet. Offshore it occurs in season on Nantucket Shoals, Georges Bank, Browns Bank, the Nova Scotian banks, and the Newfoundland banks. It was also recorded on the west coast of Greenland to Sukkertoppen and Holsteinborg. Hansen (1949) reports that dogfish were formerly a rarity around Greenland, but in the 1930's some were caught in several places on the southwest coast and in the autumn of 1947, around Sukkertoppen.

Local observations of spiny dogfish, and their seasonal occurrence, are reported by Perley (1852), Stafford (1912), Cox (1921), and Jeffers (1932). Each of these authors noted that the appearance of dogfish usually indicated an end of commercial fishing for food fishes.

TABLE 1.—*Water temperature and dogfish catches of 100 or more by otter trawl from research vessels in the Northwest Atlantic from Nova Scotia to the offing of New York, 1948-59*

Date	Depth	Bottom temperature	Catch of dogfish
	Meters	°C	Number
Feb. 3, 1959.....	180	9.4	428
Do.....	152	11.7	367
Apr. 22, 1950.....	122	9.4	560
Apr. 23, 1950.....	110	7.2	100
Apr. 26, 1950.....	219	7.8	103
Do.....	219	7.2	224
May 1, 1950.....	189	8.9	372
Do.....	183	-----	1,200
Do.....	177	8.9	475
Do.....	201	8.9	269
May 2, 1950.....	110	4.4	420
May 13, 1950.....	91	11.1	1,476
Do.....	91	11.1	152
Do.....	82	11.1	150
Do.....	81	5.0	610
May 14, 1950.....	83	7.2	258
May 15, 1950.....	142	11.1	110
May 16, 1950.....	113	7.8	120
Do.....	85	6.7	140
May 17, 1950.....	76	5.6	156
June 14, 1955.....	103	6.1	110
Weighted average.....	134	8.3	-----
July 29, 1949.....	67	10.6	3,637
Aug. 1, 1950.....	85	7.8	224
Do.....	85	8.3	455
Aug. 2, 1950.....	94	8.9	146
Aug. 5, 1950.....	293	6.1	234
Aug. 4, 1948.....	58	6.7	123
Aug. 5, 1948.....	33	13.3	131
Do.....	40	11.7	210
Oct. 8, 1958.....	204	7.8	900
Oct. 9, 1958.....	222	7.8	122
Oct. 16, 1948.....	24	12.2	374
Oct. 17, 1948.....	37	8.3	101
Oct. 20, 1959.....	55	11.1	1,050
Oct. 30, 1949.....	74	15.6	248
Do.....	76	13.3	100
Do.....	60	14.4	283
Do.....	55	15.6	115
Oct. 31, 1948.....	61	15.0	1,561
Nov. 5, 1948.....	61	14.4	187
Nov. 17, 1956.....	56	13.3	160
Do.....	56	16.7	211
Dec. 3, 1948.....	85	-----	190
Weighted average.....	85	11.4	-----

In the Pacific Ocean, Bigelow and Schroeder (1948) report that the spiny dogfish is found on "... both sides of the Northern Pacific south to California, Japan, Northern China and the Hawaiian Islands."

MIGRATIONS

The spiny dogfish is a gregarious fish and occurs in schools containing large numbers of individuals. Usually the schools are composed of: (1) very large, mature females; (2) medium-sized individuals, all mature males or all immature females; or (3) small immature individuals of both sexes in about equal numbers (Bigelow and Schroeder, 1953). Hickling (1930), in his studies of spiny dogfish collected off the southern coast of Ireland, noted a relation between the size of the individuals in the schools and the depth of water. Fish of both sexes, from 30 to 45 cm. long, were caught in 55 m., while larger fish of both sexes, from 50 to 89 cm. long, were caught in depths of 164 to 183 m. In general, male dogfish were found in shallower water than females of the same size. The exception to this, however, was for the large pregnant females that were found migrating into shallower water to bear their young.

The appearance of dogfish in our northeastern coastal waters is a rather sudden event. One day, in a given area, there will be fine cod and haddock fishing; the next day there will be nothing but dogfish. They appear as early on Georges Bank (March-April) as they do along New Jersey (March) (Bigelow and Schroeder, 1953). Dogfish are spring and autumn transients only in the southern part of their range, from New York to North Carolina, and in the Cape Cod area they are mostly transients, moving to the north in the spring and to the south in the autumn.

In Newfoundland waters they first begin to appear in June, off the southern end of the island (Templeman, 1944). The largest fish—mature and probably pregnant females—appear first. The mature males appear in the late autumn. As the season progresses, dogfish appear farther northward along the coast and are off Labrador by September. In general, dogfish are plentiful around Newfoundland from June through November or December.

The nature of the dogfish's seasonal migration—coastal north-south, offshore-onshore, or a combi-

nation of the two—is not clearly understood. Part of the problem is the mystery of where the dogfish spends its winters. Bigelow and Welsh (1925) stated, "The winter home of the Gulf of Maine dogfish is still to be learned." They examined the evidence, including the presence of the adults in deep water in Long Island Sound in mid-summer, the almost simultaneous appearance of the fish all along the coast north of North Carolina in the spring, and the capture of dogfish by the *Albatross*, February 1920, in 164 to 365 m. along the continental edge off Chincoteague, Va., and off Delaware Bay, and concluded that this "... argues for an on-and-off rather than a long-shore migration, with the deep water off the continental slope as their winter home."

More recent evidence of the presence of dogfish in deep water during the winter has been accumulated from observations of dogfish off the Middle Atlantic and New England States (Bigelow and Schroeder, 1936, 1948, 1953). In January 1961, spiny dogfish were taken in an otter trawl by the Bureau of Commercial Fisheries research vessel *Delaware* in 158 to 183 m. along the edge of the Continental Shelf 80 miles south of Martha's Vineyard.

At times, however, dogfish may come into shallow water in the winter. Collins (1883) quotes an item in the newspaper "Cape Ann Advertiser" dated February 10, 1882: "Immense schools of dogfish, extending as far as the eye can reach, have appeared off Portsmouth, an unusual sight in winter."

The accumulated wealth of evidence suggests that temperature governs the seasonal movements of the spiny dogfish. Bigelow and Schroeder (1948) note that dogfish do not appear along the east coast until the water warms to 6° C. and disappear when the water temperature rises to about 15° C. The preferred range of temperature on the offshore wintering grounds seems to be 6° to 11° C.

Survey data (table 1) collected during 1949–59 by the Bureau of Commercial Fisheries Biological Laboratory at Woods Hole indicate dogfish in the Northwest Atlantic prefer bottom water temperatures between 7.2° and 12.8° C. (average, 9.8°). The average temperature at which 100 or more dogfish per haul were caught during the period

January–June was 8.3° C.; for the period July–December, 11.4° C.

The survey data also tend to support Bigelow and Schroeder's statement that this species winters in relatively deep water, moving into shoaler water in summer and fall. The average depth at which 100 or more dogfish were caught during the period January–June is found to be significantly different from the corresponding depth for the period July–December (134 and 85 m., respectively).

In Alaska waters incidental catches of spiny dogfish are reported by Hanavan and Tanonaka (1959) during experimental gill netting for salmon. The dogfish were caught in the Bering Sea and in the Gulf of Alaska during July and August when the surface water temperatures ranged from 7° to 13.3° C.

In waters off Japan, Sato (1935) reports an interesting diurnal migration of spiny dogfish. He recorded the body temperatures of dogfish caught in the daytime and at night, on a fishing ground in depths of 110 to 128 m. Thirty dogfish caught at night in a surface drift gill net had body temperatures of from 9.5° to 11.2° C. The surface water temperature at the time was quite similar, from 9° to 12.2° C. In contrast, 28 dogfish caught during the day on a longline on the bottom had body temperatures of from 3.5° to 5.8° C. Unfortunately Sato does not report the water temperature on the bottom. It seems reasonable to assume, however, that the bottom water temperature was within the range of the body temperature of the fish caught on the bottom and that the dogfish were rising to or near the surface at night and descending to the bottom during the day.

In early August 1961, during a cruise of the Bureau of Commercial Fisheries research vessel *Delaware*, dogfish were frequently observed at or near the surface on many of the inshore Gulf of Maine fishing grounds (Robert L. Edwards, personal communication). The water temperatures at the surface were normal for the season (around 15.6° C.), but at the bottom they were abnormally cold (2.8° to 3.9° C. at 73 m.). Few dogfish were taken in the otter trawl at this time.

Edwards (personal communication) observed the dogfish appeared at the surface itself late at night and early in the morning. One morning in Ipswich Bay they were observed to be harrying small schools of euphausiids—as many as six to

eight fish circling each school. The numbers of fish that could be seen at this time were in the thousands. During the day the dogfish retreated to depths of 3 to 5 fathoms. Several hundred were handlined from this depth for tagging and for examining the embryos in the pregnant females. In the late afternoon, occasional fish were again observed at the surface. South of Cape Cod, the dogfish were taken again a few fathoms below the surface. They appeared whenever the otter trawl was hauled in and unwanted fish were discarded.

Edwards, Livingstone, and Hamer (1962) studied the distribution of fishes across the Continental Shelf from Nantucket Shoals to Cape Hatteras. Their results indicate that male spiny dogfish are usually found in cooler water than the females.

Little is known of the salinity preferences of the spiny dogfish. Bigelow and Schroeder (1948), however, note a record of a spiny dogfish that entered a river in Denmark. In their opinion the water was undoubtedly brackish at least near the bottom, rather than fresh, since both cod and *Merluccius* were also present in the river at the same time. Spiny dogfish captured off British Columbia and studied in the laboratory, were able to live for more than 1 hour in distilled water and for nearly 2 hours in tap water (Quigley, 1928a). The author concludes, "Since the dogfish continued to breathe for an average of 113 minutes in tap water and remained active during most of this time, they probably could escape from a freshwater stream even if they were to swim into it above tide water level."

TAGGING STUDIES

Spiny dogfish have been tagged over most of their range by biologists interested in making precise determinations of the migration routes of this fish, and also in learning something of the nature of the dogfish populations. Tag returns from most of the experiments have been at a lower rate than for tagging experiments with commercially valuable fishes; in most fisheries the dogfish is either a nuisance to be avoided or, at best, is retained as a very minor part of the catch. Although many tagged dogfish are undoubtedly recaptured, most are discarded at sea without having their tags noticed; consequently, few tags are recovered. Tagging returns suggest that the dog-

fish is long lived, for several fish were at liberty for 10 years. Some individual fish migrated long distances.

In a British experiment in November and December 1957, 75 spiny dogfish were tagged with a yellow plastic tab attached with a braided nylon loop (Beverton, Gulland, and Margetts, 1959). The fish were tagged incidentally during a whitening tagging experiment in the northwest part of the Irish Sea. At the time of the report, after 7 months at liberty, only two tagged dogfish were returned despite the fact that originally the dogfish appeared particularly robust and little affected by capture or tagging. No information was given as to the place of recapture of the tagged fish.

One thousand spiny dogfish were tagged near the Shetland Islands, north of Scotland, in November 1958 (Aasen, 1960). The mark used was a yellow slip of polyethylene film with printed text rolled up as a cylinder and attached to the fish with a stainless steel bridle in front of the first dorsal fin. After 2½ months at liberty, 12 tagged fish (1.2 percent) were recaptured, most of them near the west coast of Norway. After 2 years at liberty, 10.8 percent of the dogfish had been recaptured. The returns from this experiment, combined with returns from nearly 3,000 dogfish tagged in later experiments, yielded a combined return rate of 6 percent. Aasen (1962) concluded, "It is obvious that most of the fish migrate towards the Norwegian coast in winter and return to the grounds northwest of the British Isles in summer."

Holden (1962) tagged 278 dogfish in the Irish Sea during 1957-59, and 15 (5.4 percent) were recaptured. Most of the winter recaptures came from the southern part of the Irish Sea, while the summer and autumn recaptures came from Scotland, as far north as the Shetland Islands. Presumably the dogfish wintered in the Irish Sea and migrated to mingle with the Norwegian dogfish north of Scotland in the summer.

Nearly 10,000 dogfish were tagged in the waters off British Columbia and Washington in the 1940's, and 655 (6.7 percent) were recovered (Holland, 1957). In general, the tag returns demonstrated a southward, coastal migration in the autumn and winter and a northward migration in the spring and summer. Several long-distance recaptures were reported from the coastal migrations but the

one outstanding offshore, long-distance migration that was reported was when a dogfish that had been tagged off Willapa Bay, Wash., in 1944 was recaptured near the northern end of Honshu Island, Japan, in 1952. This is a straight line distance of 4,700 miles, but the author concluded that the fish probably followed a great circle route at accustomed depths along the coastal shelf. Longevity of the spiny dogfish is suggested by the above example, a fish at liberty 7 years, and two other fish tagged in the same experiment, which were at liberty 8 years and 10 years, respectively.

Dogfish tagging experiments in the Northwest Atlantic have been reported by Templeman (1954, 1958) for the Newfoundland-Grand Bank area and by Jensen (1961) for the Gulf of Maine-Georges Bank and Browns Bank areas (fig. 3). In the Newfoundland experiment, 279 females were tagged near St. John's in July 1942, and, as of September 1949, 14 fish (5 percent) were recaptured. Many of the tagged fish were caught in the local area and the Maritimes, but two were caught off Gloucester, Mass. (one in 1942 and one in

1943), a distance of 900 miles, and one was caught off Cape Henry, Va., in 1947, a distance of 1,300 miles. The last return was from the Strait of Canso, Nova Scotia, in 1949. Templeman noted (1954), "... most of the tagged fish were mature females carrying young and the recaptures show a southward late fall movement of some at least of these large pregnant females, with presumably a compensating northward movement in the spring and early summer." In an earlier report (1944) he suggested that the dogfish migrate rapidly and for long distances in the upper layers of the water.

While the tag returns reported by Templeman indicated a coastwise migration, he did report an astonishing offshore migration from a later tagging experiment (Templeman, 1958). A fish that had been tagged on the southwestern slope of the Grand Bank in June 1947 was recaptured in Faxe Bay, Iceland, in August 1957. The straight line distance between the tagging area and the point of recapture is over 1,300 nautical miles.

Returns of dogfish tagged in the Gulf of Maine area have done little to confirm either a north-

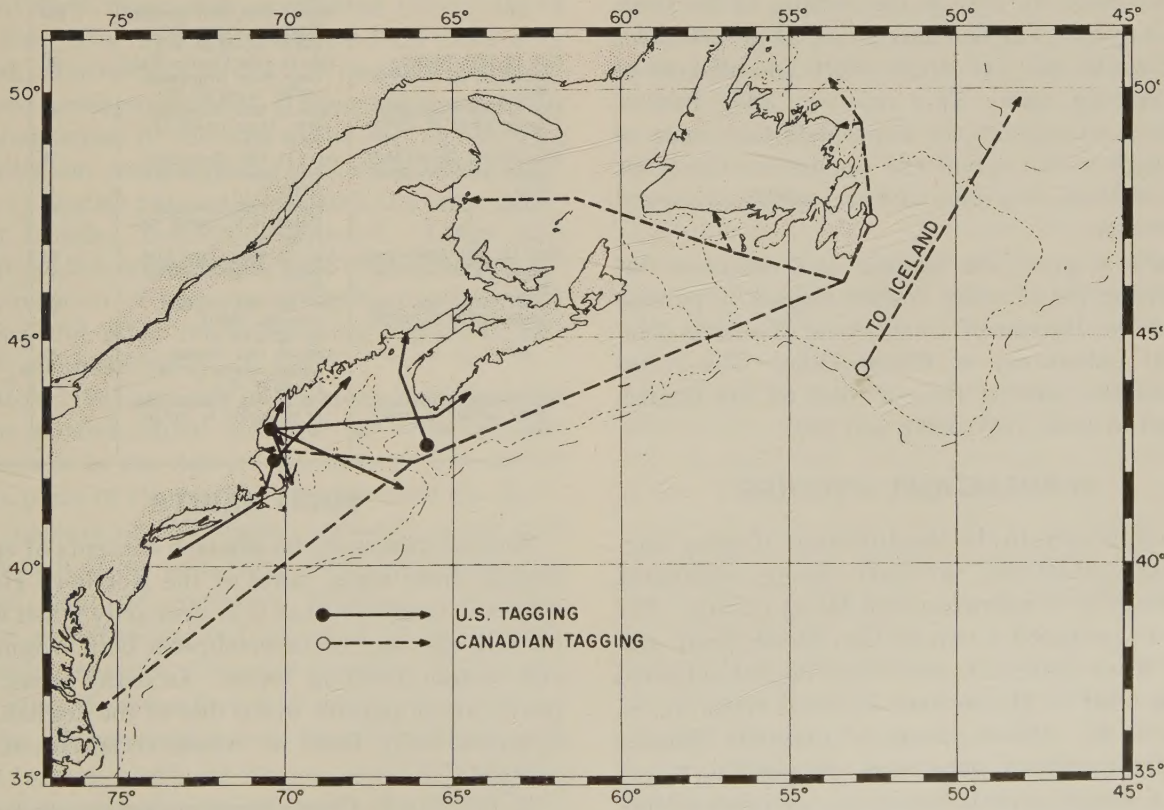


FIGURE 3.—Results of dogfish tagging in the Northwest Atlantic.

south or inshore-offshore migration pattern (Jensen, 1961). In these experiments, 155 dogfish were tagged near Cape Ann, Mass., in July 1956, and 50 were tagged on Browns Bank in October 1957. To date, nine tags have been returned (5.8 percent), eight from the 1956 experiment and one from the 1957 experiment. Most of the tagged fish were recaptured relatively close to the areas in which they had been released; six were caught less than 50 miles from the tagging area; one, 73 miles away; and another, 140 miles away. One, however, at liberty nearly 5 years, was recaptured 200 miles away, on the eastern edge of Georges Bank. In general, the recaptures suggest that spiny dogfish return to the same general area at about the same time of year and the same fish probably school together for long periods of time.

An interesting recapture was made recently of a dogfish tagged in a later series of experiments carried out aboard the *Delaware*. The fish was 1 of 143 caught on handlines in 18 m. of water, July 22, 1961. It was tagged and released 3 miles off Halibut Point, Cape Ann, Mass., and was recaptured by a commercial otter trawler in 119 m. on December 30, 1961, in the vicinity of the Hudson Canyon. The fish had moved about 250 miles in 23 weeks and was caught south and offshore of the tagging area. This recovery adds further evidence to support the hypothesis that some of the dogfish that spend the summer in the inner Gulf of Maine migrate south and offshore to spend the winter.

Table 2 gives the tagging and recapture information for 17 spiny dogfish tagged by personnel of the Bureau of Commercial Fisheries Biological Laboratory at Woods Hole. The 17 represent the returns from a total of 844 dogfish tagged in 1956, 1957, 1960, and 1961.

SEROLOGICAL STUDIES

An approach to the identification of spiny dogfish subpopulations, by blood typing techniques, was made by Sindermann and Mairs (1961). The authors proposed a two-antigen blood group system. They found that individual dogfish collected in the Gulf of Maine were of blood types S_1 , S_2 , S_1S_2 , or S_0 . Blood groups of pregnant females and their unborn pups were compatible, "... with a simple genetic hypothesis of three alleles, S^1 , S^2 , and S^0 , controlling the system." Continua-

tion of the work, complemented with tagging and other population studies, will make it possible to determine the existence of reproductively isolated subpopulations of spiny dogfish. In addition serological techniques may clarify the relationship between the various *Squalus* species and groups throughout the world.

TABLE 2.—Returns of tagged spiny dogfish

Date and locality of—		Time at liberty	Distance
Tagging	Recapture		
		Weeks	Miles
July 7, 1956, Boon Island, Maine (43°05' N.-70°28' W.).	July 22, 1957, Cape Ann, Mass. (42°44' N.-70°19' W.).	54	22
Do.....	July 29, 1959, Cape Elizabeth, Maine (43°28' N.-70°12' W.).	159	26
Do.....	July 21, 1960, Cape Elizabeth, Maine (43°27' N.-70°12' W.).	210	25
July 8, 1956, Cape Ann, Mass. (42°48' N.-70°15' W.).	Nov. 15, 1956, Cape Elizabeth, Maine (43°28' N.-70°10' W.).	18	40
Do.....	Mar. 2, 1957, Cape Ann, Mass. (42°38' N.-70°17' W.).	34	10
Do.....	May 22, 1957, Chatham, Mass. (41°40' N.-69°42' W.).	48	73
Do.....	July 16, 1959, Cape Elizabeth, Maine (42°28' N.-70°10' W.).	157	40
Do.....	May 15, 1961, Georges Bank (41°33' N.-66°35' W.).	248	185
Do.....	Sept. 4, 1961, Port Mouton Harbour, Nova Scotia (43°57' N.-64°38' W.).	274	280
Oct. 14, 1957, Browns Bank (42°36' N.-65°46' W.).	July 12, 1958, Chance Harbour, New Brunswick (44°55' N.-66°21' W.).	39	140
July 8, 1960, Stellwagen Bank (42°13' N.-70°17' W.).	June 13, 1961, Buzzards Bay, Mass. (41°32' N.-70°40' W.).	49	45
May 26, 1961, Woods Hole, Mass. (41°31' N.-70°40' W.).	June 11, 1961, Buzzards Bay, Mass. (41°36' N.-70°50' W.).	3	9
Do.....	June 15, 1962, Montauk Point, N.Y. (40°54' N.-71°39' W.).	63	64
June 13, 1961, Stellwagen Bank (42°25' N.-70°21' W.).	Aug. 22, 1962, Cape Ann, Mass. (42°46' N.-70°39' W.).	62	24
July 22, 1961, Cape Ann, Mass. (42°44' N.-70°36' W.).	Dec. 30, 1961, Hudson Canyon, (39°41' N.-72°12' W.).	23	250
Do.....	Aug. 24, 1962, Seguin Island, Maine (43°38' N.-69°37' W.).	57	71
July 26, 1961, Cape Ann, Mass. (42°46' N.-70°41' W.).	Sept. 5, 1961, Portsmouth, N.H. (43°01' N.-70°41' W.).	6	15

FOOD HABITS

Several studies of the stomach contents of spiny dogfish from many parts of the Northern Hemisphere have shown that it is primarily a fish eater but will also feed on invertebrates, both swimming and bottom-dwelling forms. In many areas, clupeoids are important in the diet of the dogfish, but it undoubtedly feeds on whatever species it can capture.

In the Pacific Ocean three important studies of dogfish feeding habits have been made. One such

study was conducted to determine the amount of predation, if any, by dogfish on salmon smolts as they descended the Fraser River, British Columbia (Chatwin and Forrester, 1953). In the river mouth, 249 dogfish were examined and 20 (8 percent) had empty stomachs. Of those that contained food, 100 percent contained eulachon (a smelt, *Thaleichthys pacificus*), or traces of it, 5 percent contained sand lance, *Ammodytes*, and 19 percent contained invertebrates, including shrimp, crabs, small crustaceans, squid, and octopus. A large number (21 percent) contained sticks and leaves, no doubt ingested accidentally with the food items. Outside the river mouth, the dogfish diet was much the same: 91 percent eulachon, 29 percent invertebrates, and 5 percent sticks and leaves. Miscellaneous food items included a honeybee and polychaete worms. On the basis of their findings the authors concluded the spiny dogfish was an opportunistic feeder.

Another study in the same general area was made by Bonham (1954) who examined more than 1,100 spiny dogfish stomachs, of which nearly 60 percent contained food. He found more than 77 different food items; fish constituted two-thirds of the diet. The three most common food items were ratfish, *Hydrolagus colliei*, (20 percent); herring, *Clupea harengus pallasii*, (18 percent); and krill, Euphausiidae, (9 percent). The only evidence of cannibalism was the finding of a 230-mm (new-born?) dogfish pup in the stomach of a large pregnant female. Bonham concluded, "Large and small dogfish eat much the same kind of food, with the exception of very small dogfish in whose diet worms and other mud-inhabiting organisms appear prominently."

Sato's (1935) studies of the spiny dogfish in the water around Japan indicate that clupeoids are important in the diet in this area as they are in other parts of the world. He examined the stomach contents of 128 dogfish collected in gill and set nets in June and July. Sixty stomachs contained fish; 48 contained sardines, *Sardinops sagax melanosticta*; and 12 contained other fishes, including herring, *Clupea harengus pallasii*, salmon *Oncorhynchus keta*, and cod, *Gadus macrocephalus*. Invertebrates were found in 21 stomachs.

In waters north of Japan, around Sakhalin, food items found in the stomachs of spiny dogfish were noted by Kaganovskaia (1937). The items

were listed simply as herring, iwashi (sardine), cod, octopus, crab, squid, and sea cucumbers.

Food habits of the dogfish in the North Atlantic are quite similar to those of the dogfish in the Pacific. From waters around the British Isles, Ford (1921) reported food items from 143 spiny dogfish with recognizable stomach contents. Fishes were found in 137 stomachs and included herring and pilchard (67 percent), mackerel (19 percent), and gadids (4 percent). Six stomachs contained crustacea, and three had mollusks. The stomachs were collected at a time when the clupeoids and mackerel were abundant and thus readily available to the dogfish.

In the Northwest Atlantic, around Newfoundland, capelin, *Mallotus villosus*, are important in the diet of the spiny dogfish. Templeman (1944) made a casual examination of 24 dogfish stomachs collected in July 1942 and found all of them contained capelin. During this month the capelin were plentiful on the inshore grounds and the dogfish appeared to be feeding almost exclusively on them. He notes, "Some of the stomachs were full of capelin, one containing 13 capelin, 1 of 7 cm. and 12 from 14 to 19 cm. long."

From August to November, Templeman (1944) made a detailed analysis of 1,171 dogfish stomachs of which 665 were empty, 367 contained only the bait used to capture them, and 139 contained food. In the stomachs that contained food, about 60 percent contained fishes, about 45 percent contained Crustacea, about 8 percent contained coelenterates, and a few contained mollusks, polychaetes, algae, and miscellaneous items. The recognizable fishes were herring (14 percent), capelin (5 percent), and cod (5 percent).

In the Gulf of Maine, spiny dogfish feed on a wide variety of species and at one time or another prey on practically all species smaller than themselves. They are regarded as the chief enemy of the cod, and also feed on mackerel, haddock, herring, squid, worms, shrimps, and crabs. They are one of the few fishes that eat ctenophores (Bigelow and Schroeder, 1953)

My own observations of spiny dogfish stomach contents have revealed a curious condition in which the stomachs were distended with a clear watery fluid. Casual observations of 50 dogfish stomachs collected during a cruise of the research vessel *Delaware* in June 1961 on Stellwagen Bank re-

vealed fish remains in only three stomachs. Five stomachs contained about 4 ounces of a light-gray, custardlike material, evidently food well advanced in digestion. Most of the stomachs, however, were filled with clear fluid; only a few stomachs were empty and flaccid.

Fifty stomachs examined at Pt. Judith, R.I., in July 1959, contained mostly amphipods (*Leptochirus*) and occasional fish remains.

In July 1961, John M. Hoberman found silver hake (*Merluccius bilinearis*) in the stomachs of dogfish collected in Ipswich Bay during a cruise of the *Delaware*. Silver hake were abundant in the area at the time.

Fishes and rock crabs (*Cancer*) were the principal food items of 33 spiny dogfish collected in June 1963 off Block Island, R.I. The dogfish were examined aboard the research vessel *Albatross IV*. Sixty percent contained fish, 33 percent contained rock crabs, and 7 percent contained squid. Recognizable food items included squirrel hake, *Urophycis chuss*; silver hake; winter flounder, *Pseudopleuronectes americanus*; and sculpin, *Myoxocephalus* sp.

It is evident spiny dogfish have no food preferences, but eat nearly anything that moves. It is evident too, they are opportunistic feeders, preying on whatever species are abundant and available. Their catholic food habits probably contribute greatly to the species' biological success.

AGE AND GROWTH

The traditional techniques used in fishery biology for age determination are not, unfortunately, applicable to the spiny dogfish. The dogfish does not have scales suitable for examination, and being a cartilaginous fish, it has no true bones in which visible growth zones are formed. Dogfish otoliths, unlike the calcareous otoliths of the teleosts, are simply aggregations of sand particles loosely joined in a gelatinous substance, and thus offer no opportunity for detection of growth zones.

A possible solution to the problem of determining the age of the dogfish is presented in an obscure Russian paper (Kaganovskaia, 1933) read in English translation. Briefly, the paper notes that the dorsal spines of the dogfish are marked with annulations apparently related to growth periodicity (fig. 4). The Russian biologist had collected the dogfish from the waters around

Sakhalin. At first she examined the vertebrae, but the barely noticeable rings in them became even less visible after treatment. Cross sections of the teeth and of the dorsal spines were examined, but without success. The teeth showed no zones, and the spines were found to have an internal cavity along their entire length. The enamel coating of the spines, however, had markings, "... which doubtless represent annual deposits."

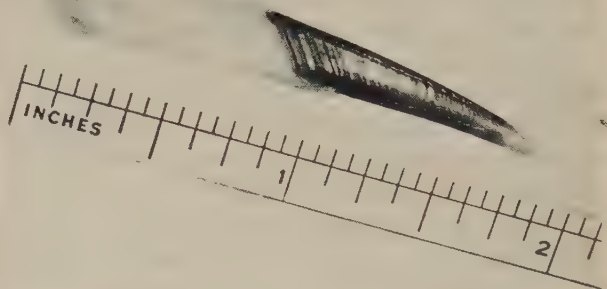


FIGURE 4.—Photograph of a dogfish spine showing the annulations.

The makeup of the spine is quite similar to the makeup of a mammalian tooth. Daniel (1934) describes the structure of the spine as follows:

For almost half its length the spine is buried in the integument. The buried part is designated as the root or base and the exposed portion the crown or spine proper . . .

. . . The spine contains a large central cavity which when in place fits over a cartilage of the fin skeleton. The walls of the spine are made of dentine which in the crown consists of a double layer. The more superficial layer is bounded anteriorly and laterally by a layer of enamel, but enamel does not extend over the posterior groove which fits up against the basal cartilage of the fin skeleton. A more or less compact layer of pigment . . . separates the enamel . . . in front from the layer of dentine.

Kaganovskaia (1933) did not try to validate the spine markings as year marks although she noted that the spines of fish less than 1 year old were light gray in color and had no markings. She examined a sample of rear dorsal spines (the posterior spines are more clearly marked than the anterior spines) from 210 dogfish, 380–1,180 mm. in length, and reported their ages as 2–25 years.

Her data were presented in a table which I have incorporated into a growth curve (fig. 5). It seems reasonable to consider the spiny dogfish a long-lived species in view of the evidence of tagged dogfish at liberty for up to 10 years.

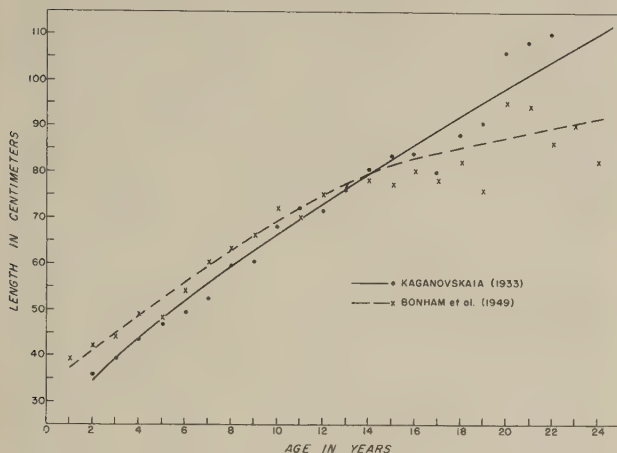


FIGURE 5.—Two growth rates for the spiny dogfish, based on interpretation of spine markings.

Using the Russian method, Bonham et al. (1949) examined the spines from 215 dogfish collected in State of Washington waters. The fish were 34–127 cm. long and 1–29 years old, and although there is variation in the Washington data, the trend is similar to that in the Russian paper. To prepare the spines for reading, Bonham (personal communication) removed them by slicing down along the bases of the spines into the back of the dogfish and freeing the spines from the skin or muscle. The spines were not treated; and low magnification (5X) or none at all was used in actual examination.

Only about 20 percent of the spines (215 out of 1,100) had markings that were sufficiently distinct to be readable without appreciable disagreement by different observers (Bonham, personal communication). In the report (Bonham et al., 1949) the authors cautioned, "It must be understood that rejection of unclear or doubtful spines would probably eliminate from consideration most of the old dogfish, whose spines usually are broken, badly eroded, and have the annulations closely crowded near the bases of the spines."

A recent study by Holden and Meadows (1962) supports the hypothesis of annual zone formation

in dogfish spines. The authors examined the spines from dogfish landed by trawlers that fished the grounds around the north and west coasts of Scotland. A total of 317 males (41.3–82.5 cm. long) and 445 females (39.6–97.5 cm. long) were examined. The ages determined were 1–19 years for males and 1–21 years for females. The rate of growth for both sexes was about the same up to the time of sexual maturity (at an age of about 9 years). After the fish became mature, the females grew faster than the males.

Comparisons between dogfish growth calculated from spine readings or length frequencies, and growth observed in tagged dogfish indicate that the growth of the tagged individuals is often half, or less, of the calculated values. Bonham et al. (1949) report that on the basis of a study of eggs and embryos, the suggested rate of growth is 7 cm. in 2 years or about 3.5 cm. per year. The rate calculated from spine readings is 3.1 cm. per year, and from length frequencies 3.3 cm. per year, but from tagging studies the rate is only 1.4 cm. per year.

In the above example, the spine readings were from fish 40–100 cm. long (2.5–21 years, indicated age). An examination of Kaganovskaia's (1933) data for fish of similar lengths and indicated ages suggests a growth of 3.5 cm. per year. Templeman (1944) calculated "... approximately 1½ cm. as the average growth per year for all mature females and 1.6 cm. for the first mature year . . ." However, a tagged dogfish at liberty for 10 years grew only about 8.1 cm. in that time (Templeman, 1958), but he concludes the fish was in worse condition when recaptured than when tagged, hence the poor growth rate. Kauffman (1955) reports the growth of two tagged spiny dogfish from the Pacific Coast as 14 cm. after 8½ years at liberty (2.3 cm./year). A dogfish tagged in British Columbia waters and at liberty almost 8 years grew 5⅝ inches (Fisheries Research Board of Canada, 1952), or about 14.1 cm. (1.8 cm./year). My own experience with the growth of tagged dogfish is limited to one specimen at liberty nearly 1 year during which time it grew only 0.7 cm.

At the present time there is no way to resolve the differences reported for the annual growth of the spiny dogfish. No doubt it is a long-lived species, attaining a maximum age of 25–30 years. The lengthy time interval between tagging and recapture, up to 10 years for certain individuals, is

perhaps the strongest evidence supporting the reported age determination studies.

LENGTH-WEIGHT RELATION

As with many fishes, female spiny dogfish grow longer and heavier than the males. Templeman (1944) reported that the immature females are slightly heavier than the males at all sizes. Mature and pregnant females are significantly heavier than either mature males or immature females. He presents a length-weight graph and lists the following lengths and average weights for dogfish from the Newfoundland area:

Length	Weight	
	Males	Mature females
	Pounds	Pounds
<i>Cm.</i>		
60.....	1.7	3.8
75.....	3.3	5.1
83.....	4.5	5.1
96.....		8.4

Pugsley (1939) reported that Pacific dogfish females tend to be heavier per unit of length than males. He includes a length-weight graph that shows this relation for males, females, and pregnant females.

Some length-weight data were collected from 210 dogfish at Point Judith, R.I., as part of a study of the Southern New England industrial fishery. These data (sexes combined) were used to calculate the length-weight relation presented in table 3.

TABLE 3.—Length-weight relation for spiny dogfish, sexes combined, Point Judith, R.I., October 1955

Length		Weight	
<i>Cm.</i>	<i>G.</i>	<i>Cm.</i>	<i>G.</i>
28.....	75	64.....	920
31.....	90	67.....	1,050
34.....	110	70.....	1,200
37.....	140	73.....	1,370
40.....	180	76.....	1,550
43.....	230	79.....	1,780
46.....	310	82.....	2,000
49.....	390	85.....	2,250
52.....	470	88.....	2,560
55.....	570	91.....	2,850
58.....	680	94.....	3,200
61.....	790		

POPULATION STATUS

The total population of the spiny dogfish is not known, although there is no doubt that it is relatively abundant and may be subject to long-term fluctuations in abundance. In the spring of 1846 they were so numerous around Gay Head, Mass.,

that 600 were caught on hooks in 1 day by the crew of a single boat (Storer, 1867).

Collins (1884) relates an eyewitness report from a fisherman who observed a school of mackerel at the surface of Wood Island, Maine, that was being harried by an immense school of dogfish in August 1880. The fisherman estimated there were about "100 barrels of dogfish" in the school. The dogfish surrounded the mackerel "... in such a manner as to inclose the mackerel on all sides and underneath, completely preventing their escape." Many of the mackerel were seen with their tails bitten off and with wounds in their flanks.

Cod as well as mackerel suffered from the attacks of the dogfish. Earll (1880) considered the dogfish to be the principal enemy of the cod and reported that adult cod in the market were seen to have teeth marks and spine wounds in their flesh, a result of attacks by dogfish. "The arrival of a school of dogfish in any locality," Earll noted, "is the signal for all other species to leave; and in this way the work of the fisherman is often suddenly terminated."

Bowers (1906) reported good groundfishing in Boston Bay in July and August 1903, but in 1904 "... horned dogfish [were] present in such great numbers that it was impossible to catch anything else."

Dogfish were much more numerous in Massachusetts Bay during the last quarter of the 19th Century and during the early 1900's than they had been previously, although in the Woods Hole region they were more plentiful before 1887 than they have been at any time since (Bigelow and Schroeder, 1953). These authors felt that perhaps the period 1904-05 marked a peak in the cycle of dogfish abundance.

It may be, however, that the population of dogfish does not fluctuate greatly but that in their seasonal migrations the main body of fish may visit one area this year and other areas next year. Our lack of knowledge about the nature of the population(s) makes it difficult to come to any firm conclusion regarding the absolute or relative numbers of fish involved.

As a result of his early studies of the dogfish around Newfoundland, Templeman (1944) said, "It is obvious ... that dogfish migrate rapidly and for long distances, and since they swim chiefly in the upper layers of water there are no hinder-

ances to migration such as the contours of the bottom offer to haddock and cod. Thus, it is quite possible that the dogfish stocks on the whole eastern coast of North American mingle sufficiently to constitute a single population."

He modified this somewhat later (1954) after analyzing his tag return data. "The distant recaptures are also numerous enough, considering the small number tagged, and occur in enough different years to show that even if there is not indeed a single population, there is at least a widespread intermingling of the populations of adult female *Squalus acanthias* on the Atlantic Coast of North America."

Exploratory cruise data indicate that, rather than being distributed relatively homogeneously over large areas, dogfish congregate in dense, localized schools. Thus, high concentrations of dogfish at a given time and locality provide no accurate indication of their overall abundance, as they may be exceedingly scarce a few miles distant. Large hauls of dogfish tend to be grouped within a period of a few days, as the vessel fishes the same general area during the interval. Similarly, consecutive tows at different depths may produce no dogfish at one depth but numerous dogfish at only slightly greater depths (table 4).

There is evidence that dogfish may vary in availability, or abundance, from year to year as well as from place to place. Data were analyzed from survey cruises of the research vessels *Albatross III* and *Delaware* (table 5). The relative abundance of dogfish, expressed as catch per 30-minute tow, was high in 1948, 1949, and 1950. Abundance declined markedly in 1955 and 1956 but was moderately high in 1958. In 1959, abundance of spiny dogfish declined once more, but during 1960-62 it reached a high level nearly on a par with the peak in 1949. The changes in abundance are also reflected in the commercial catch of dogfish (see figs. 8 and 9). No explanation exists for this apparent periodicity in abundance.

POPULATION DYNAMICS

The dynamics of the spiny dogfish population would be difficult to study now to any fine degree because much of the necessary information is lacking or is imperfectly known. Perhaps the greatest gap in our understanding of the species is a knowledge of the nature of the population itself.

TABLE 4.—Dogfish catches on Albatross III Cruise 126, by depth, temperature, and sex along Middle Atlantic Coast, January-February 1959

Transect	Date	Depth	Bottom temperature	Sex		Total fish
				Males	Females	
Martha's Vineyard...	Feb. 3	Meters	° C.	Number	Number	Number
		85	5.6	48	11	59
		116	11.7			
		150	10.6	14	353	367
		183	9.4	423	5	428
		268	8.9			
Hudson Canyon.....	Feb. 2	384		2		2
		58	7.2	10		10
		85	8.9	40	2	42
		122	11.1	5	5	10
		168	10.0			
		186	9.4			
Barnegat.....	Jan. 23	326	6.7			
		417				
		46	7.2			
		82	10.6			
		113	11.1			
		146	11.1			
Cape May.....	Feb. 1	289				
		58	10.0	53	4	57
		79	11.7	144	138	282
		113	11.7	251	466	717
		158	11.1			
		213	10.0			
Delaware Bay.....	Jan. 24	280				
		329				
		56	10.0	14		14
		75	12.2	53	66	119
		119	12.2	2	1	3
		146	11.1	1	1	2
Winterquarter.....	Jan. 25	184	11.1			
		229	9.4			
		274				
		402				
		33	10.0	58	1	59
		67	12.2	4	1	5
Cape Charles.....	Jan. 25	70	13.3	1		1
		131	11.1	17	8	25
		238				
		436				
		31	8.9			
		43	12.2	25	56	81
		76	12.8			
		141	12.2			
		196	10.0			
		317				

TABLE 5.—Spiny dogfish catch on annual survey cruises, all seasons, all grounds from Nova Scotia to Hudson Canyon, 1948-62

Year	Total tows	Tows with dogfish	Total caught	Catch per tow
	Number	Number	Number	Number
1948.....	233	57	4,551	19
1949.....	115	21	3,755	33
1950.....	339	173	10,333	31
1955.....	279	64	672	2+
1956.....	93	40	727	8
1958.....	159	63	1,923	12
1959.....	212	38	1,106	5+
1960.....	117	41	2,636	22
1961.....	161	42	3,799	23
1962.....	138	37	3,444	25

The basic plus and minus factors of natality and mortality lack adequate quantitative investigation. There have been some studies, however, of certain phases in the reproductive cycle, and these are discussed below.

REPRODUCTION

Spiny dogfish are ovoviviparous. The eggs in the female are fertilized internally by means of the

male's claspers, and the young are born alive. The period of fetal development is lengthy, perhaps up to 2 years. The number of young produced at each delivery by a female dogfish is small.

Sex Ratio

During development in the females, and presumably at birth, the sex ratio of the pups is very nearly 1:1. Ford (1921) collected 2,720 embryos at the fish market in Plymouth, England, and found 1,377 were males and 1,343 were females. Templeman (1944) counted 933 males and 931 female embryos in the uteri of 492 females collected in July–November 1942, off St. John's, Newfoundland. For dogfish in the Pacific, Bonham et al. (1949) report, "Males and females occur in equal numbers among the embryos." Aasen (1964b) examined the pups in a sample of 41 females collected in November 1958 about 100 miles west of the Orkney Islands. There were 126 males and 130 females. Our observations for dogfish in the Gulf of Maine agree with those from other waters. In July–August 1961 on a cruise of the *Delaware* in Ipswich Bay, 234 female dogfish were examined. Fifty-three contained pups, of which 155 were males and 140 were females.

From the time of birth to the time of attaining sexual maturity, the young dogfish tend to school together, but the mature adults tend to school by sex. Ford (1921) classified the schools, or shoals, as follows: (1) Shoals of large fish consisting exclusively of females, the majority in the pregnant condition; (2) shoals of medium-sized fish exclusively males in the mature condition; (3) shoals of medium-sized fish of which the majority were immature females; and (4) shoals of immature fish in which the males and females were equal in number.

Sex-size segregated schools are also reported by Hickling (1930) around Ireland, Templeman (1944) off Newfoundland, and Bigelow and Schroeder (1953) in the Gulf of Maine. In the eastern Pacific, however, Quigley (1928b) observed that the schools contained both sexes, and the data listed by Bonham (1954) for the same general area support this statement, although in individual catches the percentage of males varied as much as from 35 to 76 percent. In the western Pacific, however, Kaganovskaia (1933) observed the schools of dogfish to be segregated by sex, size, age, and depth. She notes, "... the shore-set nets caught mainly

immature sharks from 4 to 8 years of age, the bottom-set nets older fish, from 10 to 18 years, mainly males—(July–October); the drift pelagic nets—chiefly mature females." Thus, her observations agree in general with those reported from other parts of the world. I suspect that the dogfish in the eastern Pacific also school by sex despite the reports to the contrary by Quigley (1928b) and the data presented by Bonham (1954).

On the basis of the reports from areas that include the known range of the spiny dogfish, it is difficult, therefore, to determine the sex ratio of the adults because of the manner in which they school.

Size at Sexual Maturity

Sexual maturity in male dogfish is attained at a smaller size than in females, and reported studies indicate that the larger the maximum size of fish in a population, the larger the size at maturity. Table 6 lists the data extracted from reports that specifically mention average size at first maturity for the spiny dogfish.

TABLE 6.—*Maximum size and size at first maturity of spiny dogfish from several areas*

Author	Locality	Size of males		Size of females	
		Maturity	Maximum	Maturity	Maximum
Ford (1921)-----	Plymouth, England.	Cm. 59-60	Cm. 83	Cm. 70-80	Cm. 110
Hickling (1930)-----	Irish Sea-----	62	-----	70-80	-----
Kaganovskaia (1937).	Sakhalin-----	-----	-----	100	¹ 124
Templeman (1944)---	Newfoundland---	60	86	74	101
Bonham et al. (1949) -	Washington-----	72	100	92	124

¹ Sex not specified, probably a female.

Because of the age determination problem discussed earlier, it is difficult to assign an age value to the time of first maturity. Templeman (1944), however, suggests that, "... it takes the average female dogfish 9 or 10 years from the fertilized egg or 7 or 8 years after birth to reach sexual maturity." Based on the spine readings of Bonham et al. (1949), the data indicate 11 years for males and 19 to 20 years for females as the age of first maturity for spiny dogfish in waters off Washington. Kaganovskaia (1937) did not discover mature females less than 19 years old or less than 1,000 mm. long. It seems incredible that dogfish mature at such a late age, but a critical examination of the evidence offers support for Bonham's data and Kaganovskaia's statement.

The reported sizes of spiny dogfish at time of first maturity are about 72 percent (range 68–80 percent) of the reported maximum sizes for the species. This is in general agreement with similar data reported by Bigelow and Schroeder (1953) for nine species of sharks from the Gulf of Maine where the sizes at first maturity are about 62 percent (range 52–75 percent) of the maximum sizes. If we assume (1) that the maximum age (sexes combined) of the spiny dogfish is 25 to 30 years, (2) that we can equate length with age, and (3) that the largest individuals are females, then the age at first maturity of the females is about 72 percent of the maximum or about 18 to 21 years.

Mating

Although there are no recorded observations of the actual mating of spiny dogfish and no conclusive data to confirm the season of year when it takes place, the evidence presented by most authorities suggests that mating takes place during months when the water temperatures are low. Ford (1921) found newly formed embryos at Plymouth during November to May. Templeman (1944) concludes that the eggs are fertilized and pass into the uteri in February and March, but more generally in March. He cautions, however, that his lack of information about the spring temperatures when the eggs are developing may vary the dates a month in either direction. An examination of dogfish captured in the Woods Hole area suggests that ovulation probably occurs in February or March (Hisaw and Albert, 1947) and perhaps we can infer that mating and fertilization of the eggs take place soon after. Bigelow and Schroeder (1948) believe that in the Atlantic Ocean, mating probably takes place shortly after the young are born, although no definite information is available.

Reports on mating of the spiny dogfish in the Pacific Ocean tend to be contradictory, but in general support the hypothesis that mating takes place in the cold months, as in the Atlantic Ocean. Quigley (1928b) examined slightly over 200 dogfish collected in June, July, and August and found embryos that ranged in size from the smallest to those with the umbilical scar completely healed and apparently ready for birth. These observations suggested that “. . . in the vicinity of Nanaimo, *Squalus sucklii* breeds at all times of the year.” We know now, of course, that what she had seen

were the two broods of young that are typical of the species. Hart (1942) on the other hand, reporting the work of Lucas, concluded that breeding takes place during the winter and that, “. . . fertilization by the male takes place soon after the birth of the young . . .” Bonham et al. (1949) admitted that the season at which mature dogfish mate is not known, but regards as a popular misconception the belief that dogfish breed and bear young at all times of the year. Sato (1935) concluded, without much firm basis for the statement, that dogfish breed throughout the year around Hokkaido.

Fecundity

As might be expected for a live-bearer, the number of young produced per female spiny dogfish is small and the period of development within the mother is long, lasting nearly 2 years. The eggs are large and contain a great deal of yolk and have been well described by Templeman (1944). Following fertilization, and during early development of the fetus, the eggs (figs. 6 and 7) are contained in a horny capsule (“candle”) that later breaks down leaving the embryos free in the enlarged part of the oviduct (termed the “uterus”). There is no placental attachment (Bigelow and Schroeder, 1953) as with some other species of sharks, but additional material (at least water) is obtained from the uterine wall (Templeman, 1944). The reported number of pups per female probably should be considered a minimal figure. The observations were made of fish caught by otter trawls or other fishing gear and examined on board the vessel or in the market. I have seen pups that were apparently near term prematurely delivered when the females were landed on the deck of our research vessel. It seems reasonable to assume that this also happened in the studies reported in the literature. Fortunately, the number of premature pups was never very great so that the reported data may be accepted with a fair degree of confidence.

The greatest number of pups per female was reported by Kaganovskaia (1937) who recorded 5 to 19, with an average of 11, for the spiny dogfish near Sakhalin. The least number of pups per female was reported by Templeman (1944) who recorded 1 to 7, with an average of 4, for the dogfish near Newfoundland. Ford (1921) reported 1 to 11, mostly 2 to 4, from England, while from the



FIGURE 6.—Spiny dogfish egg collected July 1961 in Ipswich Bay. Note the embryo, probably about 4 months old.

West Coast of North America, Quigley (1928b) reported 3 to 11 (average 7), Clemens and Wilby (1961) reported 3 to 14, and Bonham et al. (1949) reported 2 to 17, mostly 7 to 8. Female spiny dogfish collected about 100 miles west of the Orkney Islands contained 2 to 13 pups, with an average of 6.2 pups per female (Aasen, 1964b).

In the Gulf of Maine, Bigelow and Schroeder (1953) state that the number of pups per female may be as many as 8 to 11, or as few as 2, but mostly 4 to 6. Data collected in July–August 1961, in the inner Gulf of Maine (Ipswich Bay), show the females may contain from 1 to 11 pups, mostly 4 to 7.

To examine the relation between the size of pregnant female and the size and number of pups (fetuses) per female, I grouped the data by length of females by 3-cm. groups (table 7). In addition to the data for fetuses, the measurements and numbers of embryos are also included.

TABLE 7.—*Fecundity of spiny dogfish examined aboard R/V Delaware, 1961*

Length	Females with embryos	Embryos		Females with fetuses	Fetuses	
		Average per female	Average length		Average per female	Average length
Cm.	Number	Number	Mm.	Number	Number	Mm.
60.....	1	5.0	4			
63.....						
66.....						
69.....						
72.....						
75.....	1	5.0	5			
78.....	1	3.0	5	2	4.5	154
81.....				2	6.0	190
84.....	2	4.5	3	6	4.7	186
87.....	6	4.5	9	6	3.7	194
90.....	4	4.2	12	14	5.6	197
93.....	4	6.2	7	9	5.6	194
96.....	1	9.0	6	5	7.2	197
99.....				8	7.9	205
102.....	1	3.0	20	1	8.0	220

The data suggest that the larger females tend to have slightly more and slightly larger pups than the smaller females. This, in general, agrees with the reports from other parts of the range of the spiny dogfish. A comparison between the aver-

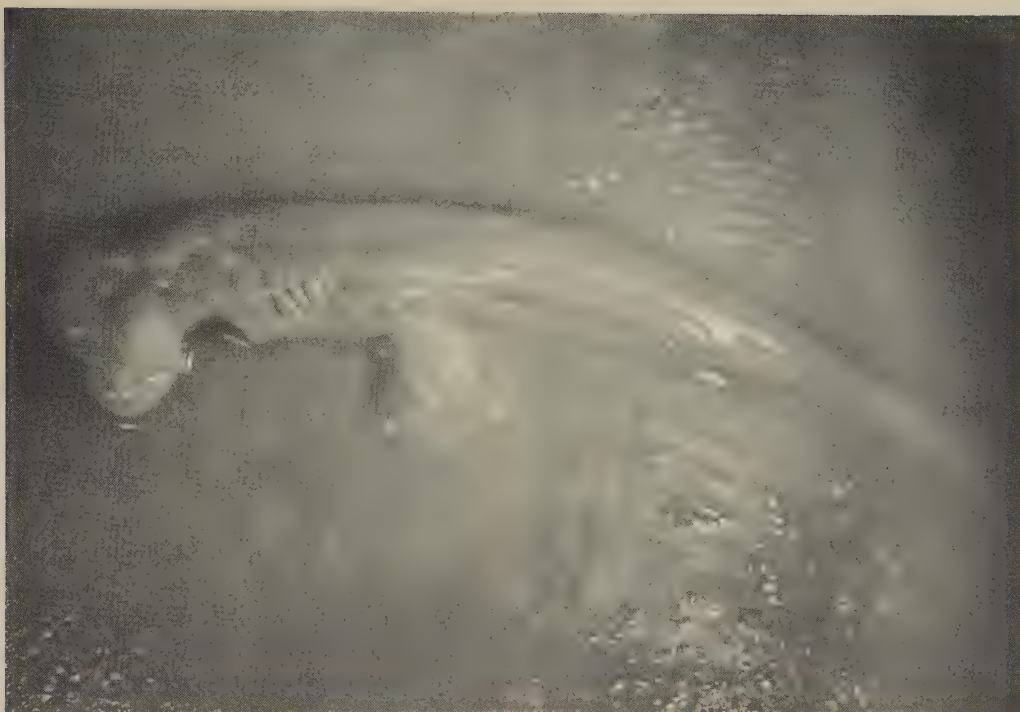


FIGURE 7.—Microphotograph of the embryo shown in Figure 6. Actual size of embryo is 19 mm.

age number of embryos per female and the average number of fetuses per female seems to indicate there is very little loss (mortality?) between the two stages of development. The size of the young dogfish at the time of birth is 20–30 cm., regardless of the part of the world from which the observations are reported (table 8).

TABLE 8.—*Size of dogfish at birth*

Author	Locality	Reported size of dogfish pups
		Cm.
Ford (1921).....	Plymouth, England.....	25–31.
Hickling (1930).....	Irish Sea.....	About 26.
Kaganovskaia (1933, 1937).....	Sakhalin.....	Average 24.
Templeman (1944).....	Newfoundland.....	24–31.
Hisaw and Albert (1947).....	Woods Hole, Mass.....	25–30.
Bigelow and Schroeder (1948).....	Gulf of Maine.....	22–33.
Bonham, et al. (1949).....	State of Washington.....	Average 27.
Aasen (1964b).....	Orkney Islands.....	Average 26.

Process of Birth

There are two recent instances of spiny dogfish giving birth to young in tanks at the Bureau's Woods Hole aquarium. In one instance, I suspect the female aborted rather than having a normal, full-term delivery.

The first dogfish was caught with hook and line October 19, 1962, in water about 27 m. deep. The

surface water temperature was 14.2° C. The fish was placed in the aquarium the same day, in water of the same temperature, and apparently adjusted well to the tank conditions. On November 22, 1962, during the night, she gave birth to three pups that measured 20.0, 20.3, and 20.7 cm. None of the pups had any evidence of the yolk sac except for a small scar on the ventral surface between the pectoral fins where the yolk sac had been attached. Presumably the yolk had been resorbed and the pups were fully developed. The water temperature in the tank at the time was 8.4° C. The pups did not survive, although the mother continued to live for several weeks until she was sacrificed.

The second dogfish was collected in a fish trap and placed in the aquarium on July 24, 1963. The next day the aquarium attendant observed the delivery of two pups. The female was resting motionless at a slight incline on a pile of rocks in the tank. Two pups were delivered simultaneously, head first, in rhythmical movements that suggested uterine contractions during mammalian birth. Delivery of the two pups took about 10 minutes. The female also delivered four more pups, but the aquarium attendant had been called

away and could not observe the delivery. An hour later, about 2 cm. of the caudal fin of a pup could be seen protruding from the female's vent. This pup was not delivered, and the female died later in the day. The average length of the pups was 21 cm., and each had a yolk sac attached. Although their size suggests the pups were nearly full term, presence of the yolk sac indicates they were still developing. Presumably the female aborted, perhaps from the shock of capture and handling or perhaps from the water temperature. The surface water temperature in the trap was 19.5° C. and the tank temperature was the same. This is well above the temperature where the species is commonly found.

When the female was examined, post mortem, the partially delivered pup was found to be held by one dorsal spine in the anterior part of the female's left uterus. The dogfish pup is morphologically suited to head presentation in birth. No doubt the caudal presentation noted here was accidental; the rearward sloping dorsal spines—small as they are—deter smooth, tail-first movement out of the uterus. It is not known if partial delivery occurs among dogfish in the sea, and none has been observed aboard our research vessels.

Season of Birth

The gestation period of dogfish is nearly 2 years, although the authorities differ in the exact number of months involved. Birth generally occurs in the cold months of the year. Ford's (1921) extensive studies at Plymouth led him to conclude that gestation occupies 21–25 months, with the fetuses ready for birth from August to December. Hickling (1930) confirmed Ford's findings. Templeman (1944) suggested a gestation period of almost 24 months with birth between January and May. Assen's (1964b) data suggest that in the offing of the Orkney Islands, dogfish pups are ready for birth in late November or soon after.

A somewhat shorter gestation period for dogfish captured in the vicinity of Woods Hole is reported by Hisaw and Albert (1947) who state, "The gestation period apparently covers about 20 to 22 months and a female gives birth every other year." The pups, they note, are born in the late fall, somewhere south of Woods Hole. Bigelow and Schroeder (1953) report a gestation period of 18 to 22 months with birth probably taking place on the offshore wintering grounds, although some

may be born in the spring and summer. Latham (1921) confirmed that some may be born in the summer when he reported many young dogfish only a few hours old that were caught in a fish trap in Long Island Sound in August.

In the Pacific the gestation period is 2 years with birth taking place during the winter (Hart, 1942), more specifically in November and December (Bonham et al., 1949).

An individual female produces young only in alternate years (Hart, 1942; Hisaw and Albert, 1947; Bonham et al., 1949; Clemens and Wilby, 1961). The data presented by Ford (1921), Hickling (1930), and Templeman (1944) confirm the broods-in-alternate-years conclusions of the workers cited above.

MORTALITY

The spiny dogfish has few enemies and is cannibalistic only to a very small degree. Thus, except for disease, there is little to act as a deterrent to the buildup of dogfish populations, and this no doubt is one of the prime reasons for the vast numbers of dogfish reported in one area or another. The predators of the spiny dogfish are mostly the large sharks and large bony fishes. In table 9, I have listed the predators as reported in Bigelow and Schroeder (1953) and noted certain appropriate remarks. It should be stressed that in all but two of the instances the prey is specifically identified as the spiny dogfish. The remaining two instances were simply listed as "dogfish" and possibly may be the smooth dogfish.

TABLE 9.—Predators of the spiny dogfish

Predator	Remarks
Mackerel shark (<i>Lamna nasus</i>).....	Known to prey on spiny dogfish in the eastern Atlantic; probably Gulf of Maine also.
Maneater (<i>Carcharodon carcharias</i>)..	One spiny dogfish, evidently torn off a line trawl.
Tiger shark (<i>Galeocerdo cuvier</i>).....	Dogfish (species ?) from one captured in Woods Hole.
Blue shark (<i>Prionace glauca</i>).....	Preys on spiny dogfish in northern waters.
Barndoor skate (<i>Raja laevis</i>).....	Spiny dogfish from Woods Hole records.
Lancefish (<i>Alepisaurus ferox</i>).....	Small spiny dogfish eaten by Block Island specimen.
Tuna (<i>Thunnus thynnus</i>).....	Swallowed whole dogfish (species ?) weighing 8 pounds.
Tilefish (<i>Lopholatilus chamaeleonticeps</i>)..	One contained two spiny dogfish.
Goosefish (<i>Lophius americanus</i>).....	One contained a spiny dogfish 1 foot long and the vertebral columns of 6 others.

Marine mammals apparently are not a threat to the dogfish. In a study of the food habits of seals (Fisher and Mackenzie, 1955), dogfish remains

were found in the stomach of a grey seal (*Hali-choerus grypus*) but constituted only 1 percent of the volume of the stomach contents. Killer whales (*Grampus orca*) may feed on dogfish, but probably only when other food is unavailable. One killer whale was seen, "Scavenging round longlining vessel, eating dogfish." in the Strait of Belle Isle, July 1953 (Sergeant and Fisher, 1957). No doubt the relatively large size, spines, and tough, scabrous skin of the dogfish are effective deterrents to predation.

UTILIZATION OF THE SPINY DOGFISH

The dogfish is not completely valueless or useless. It has some slight value, in limited quantity, in the United States, and it has greater value in some parts of the world where it is sought as a food fish. The greatest value of the dogfish in North American waters is as an industrial fish for processing into oil and meal, and at one time it was under intense exploitation for its liver as a source of natural vitamin A (fig. 8).

The Bureau of Commerical Fisheries collects and publishes yearly summaries³ of U.S. fisheries by regions. In this paper, data collected from the Puget Sound, Middle Atlantic, and New England regions are discussed. The data given in table 10, and shown in figures 8 and 9, are taken from various sections of the statistical reports.

TABLE 10.—Catch of grayfish¹ at principal regions, 1915–61

Year	New England States		Middle Atlantic States		Puget Sound, Wash.	
	Catch	Value	Catch	Value	Catch	Value
	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
1915					7,093,996	15,959
1919	63,667	184				
1922					6,359	22
1923					53,400	70
1924	21,950	367			97,005	247
1925					41,549	86
1926			6,755	347	290,395	1,452
1927					89,707	449
1928	206,309	3,312			3,203	16
1929	213,306	2,829	38,605	552	286,419	1,060
1930	93,196	3,049	12,690	267	371,180	1,309
1931	44,330	454	4,796	90	778,560	2,335
1932	27,049	374	8,140	81		
1933	13,428	151	6,739	135		
1934						
1935	35,300	733	115,500	2,053	277,500	527
1936					330,700	764
1937	31,600	578	57,700	545	1,620,100	14,360
1938	46,200	1,111	102,200	1,021	578,100	4,153
1939	85,700	1,124	47,800	478	2,365,200	17,738
1940	575,500	19,426	51,800	1,009	3,341,100	36,504
1941 ²	575,500	19,426	51,800	1,009	23,532,300	751,620

See footnotes at end of table.

³ Fishery statistics of the United States, 1919–63, U.S. Department of the Interior, Fish and Wildlife Service, and predecessor agencies.

TABLE 10.—Catch of grayfish¹ at principal regions, 1915–61—Continued

Year	New England States		Middle Atlantic States		Puget Sound, Wash.	
	Catch	Value	Catch	Value	Catch	Value
	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
1942	89,700	1,637	127,300	3,802	16,932,400	668,863
1943	53,300	1,446	47,300	1,959	22,021,500	1,243,858
1944	31,100	565	6,600	200	39,513,700	2,094,217
1945	107,600	2,472	31,000	1,211	22,149,100	1,063,149
1946	24,000	455	54,200	3,327	20,991,800	1,366,513
1947	55,100	775	21,200	1,046	14,984,800	954,535
1948	625,200	5,718	3,000	150	12,302,700	711,125
1949	111,200	1,171	37,200	1,829	10,587,000	447,828
1950	39,600	539	42,700	1,857	1,914,600	33,197
1951	11,200	254	63,700	3,051	2,412,900	58,750
1952	9,000	<500	42,700	1,857	2,981,400	47,535
1953	2,000	<500	65,000	3,000	2,225,600	17,669
1954	7,000	<500	61,000	3,000	2,008,800	19,931
1955	486,000	4,000	86,000	3,000	1,935,300	14,029
1956	1,287,000	10,000	60,000	2,000	1,526,400	12,808
1957	893,000	8,000	55,000	2,000	1,860,900	33,390
1958	763,000	6,000	50,000	1,000	4,233,100	26,675
1959	1,006,000	7,000	71,000	3,000	3,091,900	28,189
1960	970,000	6,000	52,000	2,000	1,378,400	6,931
1961			70,000	3,000	790,700	3,953

¹ Grayfish is the market name for dogfish.

² No survey on east coast. Data reported were those collected in 1940.

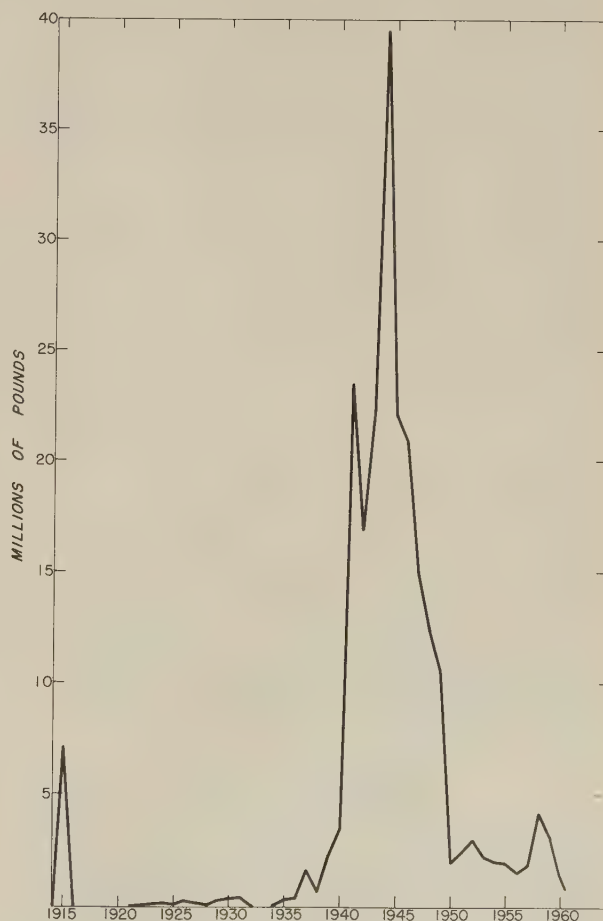


FIGURE 8.—Dogfish catch from Puget Sound, Wash., 1915–61.

The fishery for dogfish on the west coast of the United States has been studied by Alverson and Stansby (1963), who discussed the technological developments in the use of dogfish and some methods for control of the extensive populations. They reviewed the fishery and its effects on the abundance of the dogfish and recommended that an economic use be developed for the dogfish and that research be instituted to determine the biological effects of control of the species.

The possible uses of dogfish are the subject of an extensive review by Osterhaug (1961), who included a bibliography of 166 references on the subject. The first part of the review discusses the significance of the urea content of dogfish flesh. The second part discusses possible uses including animal feeds, particularly for ruminants that are able to utilize urea in their diets.

The fishery for dogfish on the east coast of the United States was never as intensive, nor did it ever reach the heights reported for the fishery on the west coast. However, from time to time the east coast fishery was active for oil, guano, meal, and human food (fig. 9). Details of the fishery are outlined below.

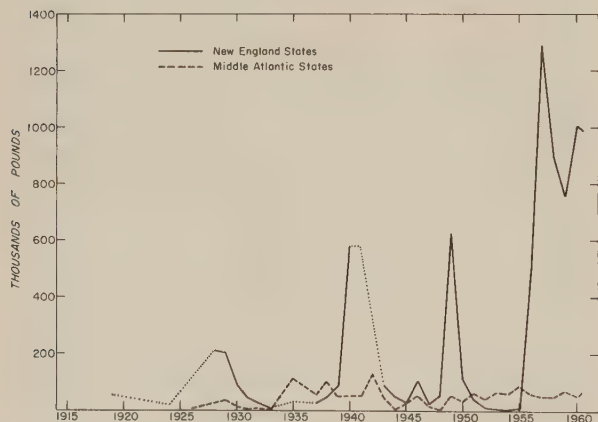


FIGURE 9.—Dogfish catch from the New England and Middle Atlantic States, 1919–61.

INDUSTRIAL USES

One of the earliest mentions of an industrial use for dogfish was made by Perley (1852), who reported on the species in the Gulf of St. Lawrence. He noted that the skins were used by cabinet makers to polish hardwood, the livers were used for oil, and the carcasses were dried and fed

as a winter food supplement to cattle. Pigs in particular were said to thrive on this diet.

Reduction for Oil and Meal

A fishery for dogfish existed around Provincetown, Mass., during the late 19th century and was prosecuted with handlines baited with silver hake (Storer, 1867). The fishery took place in September through November when the dogfish appeared in the area during their seasonal migration. Only the livers were wanted for their oil—one thousand livers yielded one barrel of oil—and the oil was sold to tanners and curriers for preparing and treating leather.

In other places, the whole dogfish was used for reduction, especially when more desirable species such as menhaden were less abundant. A menhaden reduction plant in East Boothbay, Maine, processed dogfish for oil and guano (Gallup, 1883). The fishermen were paid \$1 per 100 fish, but it was suggested that the Federal government pay a subsidy to encourage greater fishing effort. Spiny dogfish was the principal species used for oil and guano when a guano factory was established at Woods Hole (Smith, 1898), but a scarcity of the species in the season of 1897, and the general irregularity of their supply, caused the factory to turn to menhaden for raw material.

Many early writers tried to stimulate utilization of the dogfish by citing the different ways the fish could be used. I. Field (1907) mentions that dogfish oil (liver oil?) was used for illumination in some areas and that on Cape Cod the carcasses were dried and used for fuel. G. Field (1912) reports that on Cape Breton Island dogfish were dried on fences and fed to horses as a diet supplement and the well-yolked eggs were used experimentally as a substitute for hen's eggs to tan leather.

Barraclough (1953) cites interesting historical information about the early uses and developments of dogfish oils in and around the coastal areas of British Columbia. The local Indians processed the livers and used the oil obtained for dressing skins and hides. Later, as lumbering operations began in the area, the oils were used to lubricate skidways on logging roads. The oil was used extensively for lubrication and illumination in sawmills, coal mines, and coastal lighthouses. Most of the oil was processed in small home-type operations, but in 1877 the first large commercial

factory was established for oil production. It is worth noting here that during the time of World War I (1916–18) almost the entire catch of dogfish from British Columbia was exported as “grayfish” to the U.S. fresh fish market.

Extraction of Vitamin A

No doubt the greatest industrial use of the dogfish took place about 1937–47 when the species was fished intensively in Puget Sound and surrounding waters. Their rich, oily livers were in demand as a valuable source of natural vitamin A. The livers contain 50–75 percent oil, and the vitamin A content of the oil is 5,000 to 30,000 U.S. Pharmacopeia (U.S.P.) units per gram (Harrison and Samson, 1942).

The first extraction of vitamin A from shark liver oil was begun on a commercial scale about 1936–37, and the dogfish fishery was underway in Puget Sound in 1937–38 (Harrison and Samson, 1942). The fishery was on a small scale until about 1940, then, with the entry of the United States in World War II and the loss of foreign sources of vitamin A from cod liver oil, the fishery increased in intensity. In 1940 the average price paid to the fishermen for the livers was 5.7 cents per pound, but by 1943 the average price was 46 cents per pound and at one point reached a high of 54 cents (Bonham et al., 1949). The intensity of the fishery undoubtedly had a marked effect on the size of the dogfish population. Barraclough (1953) reports a decline in availability of the species in Hecate Strait beginning in 1944.

Dogfish liver oil has high vitamin A potency. Bonham et al. (1949) note that oil rendered commercially from livers of dogfish taken in the waters in and around Washington varies from 5,000 to 25,000 U.S.P. units of vitamin A per gram. The vitamin values increase several hundred percent when the fish attain sexual maturity, and the content is greater in winter than in other seasons. In contrast, Templeman's (1944) laboratory extractions of vitamin A from Canadian dogfish liver oil ranged from 300 to 19,700 U.S.P. units per gram with an average value for immature females of 1,183 units, for mature males of 1,662 units, and for mature females of 2,780 units. (For purposes of comparison, pharmaceutical cod liver oil must contain not less than 850 U.S.P. units of vitamin A per gram (Bailey, 1952).) Hirao, Yamada, and Kikuchi (1959) report vita-

min A values of spiny dogfish flesh from 329 to 5,220 U.S.P. units per 100 grams of flesh. Liver oil from the same fish contained from 2,080 to 38,800 U.S.P. units of vitamin A per gram.

Following the end of World War II, two major events occurred that had a devastating effect on the west coast fishery for dogfish. First, foreign sources of vitamin-rich fish oils again became available, and second, vitamin A was synthesized in 1947. Soon after this the dogfish fishery collapsed except for relatively small volumes landed for reduction and an extremely limited food market.

During World War II the Canadian government became interested in the east coast dogfish liver oils and their vitamin content, but the prices paid to the fishermen were too low to develop a fishery (Templeman, 1944).

Oils obtained from dogfish are of value today chiefly as raw materials for other industrial processes. The liver oil is sulfurized and used as a rubber extender, and the body oils are used in the tanning of leather (Bailey, 1952).

New England Industrial Fishery

The late 1940's saw the beginning of a new kind of fishery in New England—the so-called trash or industrial fishery—in which nonfood species, including spiny dogfish, were landed in great quantities for reduction to meal and oil. Sayles (1951) marks 1948 as the start of the trash fishery at southern New England ports with the processed meal destined for use as supplements in hog and poultry feeds.

The amount of dogfish used was small at the start of the industry. For example, the species composition of a sample from one boat that landed at New Bedford in October 1949 included only 1 dogfish in the sample of 536 fishes (Snow, 1950), but by 1956, 259,000 pounds of spiny dogfish were landed by the industrial fleet at New Bedford (Edwards and Lux, 1958). The dogfish represented 1 percent of the total industrial landings and were caught off No Mans Land, mostly in November and December.

In 1957 the Southern New England industrial landings of spiny dogfish were slightly more than 5 million pounds (3 percent of the total), with most of them landed at Point Judith, R.I. (Edwards, 1958a). There were two peaks in the landings of dogfish, one in the spring and one in

the fall, no doubt representing periods when they were locally abundant during their migrations. The industrial fishery fleet at Gloucester caught quantities of dogfish off Cape Ann, Mass., on Stellwagen Bank, and off Nauset, Mass., although the volume landed represented only from 1.5 to 3 percent of the total pounds landed (Edwards, 1958b).

Reduction plants do not like to process large amounts of spiny dogfish because they yield only meal, with very little oil, and there are serious mechanical problems involved in handling the species. The rough skin of the dogfish causes these fish to jam conveyor belts, and to pack in bins and chutes. The collagen in the carcasses clogs screens (Tarr, 1958). Tarr also states that the dogfish result in a poor yield of meal compared to other fishes.

Change in the design of processing machinery is suggested as one way to overcome the problems in handling dogfish carcasses. For example, installation of grinders designed specifically for dogfish may solve the jamming problem, but further technological research is needed before dogfish carcasses can profitably be used (Alverson and Stansby, 1963).

The rapidly expanding pet-food industry has been suggested as a potential user of great quantities of dogfish. Jones (1959) reports that on the Pacific coast the estimated potential annual production of dogfish for dog and cat food is on the order of 60 to 80 million pounds.

FOOD USES

A vast protein food resource is wasted each year in the United States because only infinitely small amounts of spiny dogfish are used for human food. Under present economic conditions, however, and because of prejudice toward eating shark flesh, it probably would be most unprofitable to fish and market dogfish for human food.

The repugnance (and perhaps fear) that most people feel towards sharks in particular does not help to make dogfish popular as a food fish. The very name "dogfish" connotes something not suitable for humans. Efforts to disguise the species under a euphemism have included simply not mentioning what it was. Thus, Field (1907) reports it was served as "fish" on two occasions in the Marine Biological Laboratory (Woods Hole)

mess hall and enthusiastically accepted by the unsuspecting diners. It has been served experimentally in hotels and listed on the menu as "Japanese halibut." In England, dogfish are gutted, skinned, beheaded, and marketed as "flake" and "rock salmon" and are widely used as one of the ingredients in the popular carryout dish, fish-and-chips.

In the United States during World War I, a great effort was made to popularize a number of relatively unexploited fishes to increase their acceptance by the consumer and thus relieve the war-induced meat shortage. Spiny dogfish was one such fish, and it was dubbed "grayfish," the name by which it is marketed today. A 14-ounce can of grayfish sold retail for 10 cents, and a Government circular (U.S. Bureau of Fisheries, 1916) was published in which 17 different recipes for preparing grayfish were listed.

Canned grayfish did not prove to be a practical solution to the problem of dogfish utilization. Corrosion of the cans, caused by changes in the chemistry of the meat, and the offensive ammonia smell that developed caused the buying public to reject the product. The flesh of dogfish, as with other elasmobranchs, contains large amounts of urea, which rapidly decomposes to form ammonia (Mavor, 1921). Fresh and frozen dogfish tissue contain about the same amounts of urea (0.9–1.5 percent), and hydrolysis, with the subsequent release of ammonia, occurs in the frozen flesh (Benson, 1924). Moyer, Southcott, Baker, and Tarr (1959) tested several methods of storing fresh dogfish flesh for periods up to 21 days. The storage included in ice and in refrigerated sea water, with and without added antibiotics (chlorotetracycline). They concluded, "... dogfish, when stored under nearly ideal conditions, appear to spoil no more rapidly than most other sea fish." It seems obvious though that dogfish is best eaten when very fresh.

The keeping quality of dressed dogfish was further studied by Southcott, Moyer, Baker, and Tarr (1960). The fish were stored in individual polyethylene bags at 0°, 5°, and 10° C., with a control lot unbagged in crushed ice. The experiment lasted 21 days. Each day two fillets were cut from a single fish from each treatment and used for bacteriological and chemical determinations. The authors found that, "Less ammonia and

trimethylamine were produced in iced fish samples than in bagged fish samples at 0° C., although bacterial counts in the two treatments were comparable." They suspected, however, that the melt water from the ice leached some of the chemical products from the flesh. Bacterial and chemical values rose rapidly at 5° C. and 10° C., and these treatments were ended at 17 days and 8 days, respectively. In general, pronounced ammonia odors were noted in only a few samples, and these were "strongly masked" by putrid odors.

Dogfish flesh is quite palatable and may be prepared in a variety of ways. My family and I have eaten fried dogfish fillets and enjoyed the meal. The fillets are easily cut from the fish and easily skinned. The meat is bone-free and white and has a flaky consistency and firmness similar to haddock fillets. The flavor is mild, and the frying produced no odors other than would be expected with any fish.

Dogfish fillets were prepared in several different ways and eaten by a test panel at the University of Washington in 1959 (Liston, 1960). The steamed fillets were rated very good and brined and smoked dogfish was well accepted. In a comparison between fishsticks made with dogfish and two brands of fishsticks bought in a retail store, those made with dogfish were rated as first or second preference by all panel members.

Dogfish is popular in Europe today as a food fish, not only in England but also in Continental Europe. In 1960, 25,600 metric tons, worth nearly 11 million kroner (1 krone is about (U.S.) 14 cents), were landed by Norwegian fishermen and shipped to England (Food and Agriculture Organization of the United Nations, 1961). It is marketed both in steak and fillet form.

A small but steady market for dogfish (listed as grayfish) exists in New York's Fulton Fish Market where it has an ex-vessel value of 3-4 cents per pound but has gone as high as 8-10 cents per pound.⁴ The fish are mostly incidental to otter trawl catches of other food fishes. The dogfish are gutted, skinned, and cut into small pieces, and sold at retail mostly to buyers of southern European extraction (Italians, Portuguese, Greeks), Chinese, and Negroes. Some retailers

fry the pieces to order for "fish and chips." (Farther south on the Atlantic coast, in the Chesapeake States, the species sold as grayfish is the smooth dogfish.)

MANAGEMENT OF THE SPECIES

The problem of the spiny dogfish as a pest of the commercial fishermen has led to a search for some method to control the species and at least reduce their numbers to the point where they would no longer constitute a problem. Many ideas have been advanced—some quite fanciful—including the usual solution to such pest problems, the payment of bounties for their capture. Unfortunately, most of the schemes suffer from a lack of, or incomplete, knowledge of the life history and habits of the dogfish.

Some of the earlier control methods proposed were based on methods used to control terrestrial pests. Atkins (1904) recounts a few suggestions offered by the public as to how the dogfish problem might be handled. Among these are the following: (1) Attach streamers, bells, chains, etc. to hundreds of dogfish and release them to frighten off the school (like bellringing a rat in a pack); (2) inoculate some of the dogfish with a fatal disease organism, such as had been done with rabbits in Australia; (3) dynamite the dogfish schools when they appear; (4) employ Government boats and men to capture the dogfish, until the plague is reduced; (5) pay a bounty to fishermen for capturing the dogfish; and (6) use long seines of strong cord, 41,000 yards or more in length, and surround the schools as is done with the schools of sharks in India.

The best control method, however, would be greater utilization of the dogfish, particularly as human food. Or, as Atkins stated it: let the public "... apply their teeth and eat the dogfish up."

Increased use of the species, particularly industrial utilization, carried out over a period of years, would undoubtedly reduce the numbers and keep them at a relatively low level. There is evidence that short-term programs designed to reduce the dogfish population, particularly if carried out in local areas, are not successful. Templeman (1944) notes, "In Placentia Bay alone during the 1938 attempt to reduce dogfish numbers, about 10,391,000 pounds of dogfish were caught or approx-

⁴ Ledner, J. F., 1964. Fishery products report, N-252, Dec. 29, 1964. U.S. Bureau of Commercial Fisheries, Market News Service, New York, N.Y., 4 pp. [Unpublished processed report.]

imately 2 or 3 million fish without any apparent diminution of the supply."

The results of increased exploitation of the North European oceanic stock of dogfish are discussed by Aasen (1961, 1963, 1964a, 1964b). In the period 1957-62, the Norwegian catch of dogfish increased by 50 percent. Returns from dogfish tagged in 1958-60 indicated an annual fishing mortality rate of 7 percent and an annual natural mortality rate of 20 percent.

During the 1961-62 fishing season, there was an annual mortality rate of 38 percent. (Aasen did not separate fishing and natural mortality.) And he reported (1964a) an average total instantaneous mortality rate of 72 percent in the years 1960-63. He interpreted the high figure as a "danger signal." A measure of catch per unit of effort for the period 1957-63 "... shows a heavily declining stock [of spiny dogfish]."

The evidence presented by Aasen in his several papers, and by Barraclough (1953), shows that long-term exploitation of the dogfish can produce a real reduction in their numbers. Thus, increased fishing effort on the dogfish off the United States could bring about some marked changes in the size of the population. It is not unreasonable to suspect that future fishery biologists might be called on for studies to save declining dogfish stocks in North American coastal waters.

If increased use of the dogfish is not feasible, either for food or industrial purposes, some other method of control should be investigated. A rather unique method—the sterile-male technique—has been used successfully to control the screwworm, an insect pest of cattle, and may prove of some value in the case of the spiny dogfish. The method is described by Knipling (1959) and, briefly, involves sterilizing laboratory-reared male screwworms through the use of gamma irradiation. The treated males are released in the area of infestation in the ratio of 5 to 10 times the number of normal males. Females that mate with the sterile males lay infertile eggs, thus reproduction is greatly reduced. The treatment has been successful in eliminating the pest on the island of Curacao and controlling it in Florida. Knipling states that this control method is based on the following biological principle: "The introduction of sexually sterile but otherwise sexually vigorous males, and to a lesser extent females, into the

natural population of an animal species will have greater influence in reducing the biotic potential of the population than elimination of the same number of individuals from the same population by destruction or removal." The sterilization could be done either by irradiation or with chemicals.

It would be difficult at the present time to try to evaluate on a theoretical basis the sterile-male technique applied to the spiny dogfish problem. We lack some very necessary knowledge of the life history of the species. For example: (1) How many dogfish need to be sterilized to effect control (that is, how many dogfish are present in the total population), (2) how many times in its lifespan will a dogfish mate (screwworms mate once), and (3) does one male dogfish mate with more than one female in a given season?

The low fecundity of the spiny dogfish and the long period of gestation are factors very much in the favor of any control method that might be applied. But mere control is not a very satisfying solution to the problem of dogfish abundance. From a conservation standpoint it would be more desirable, of course, to find a use for what is very obviously a rich potential resource. It is possible that in future years, when additional sources of animal protein are needed for human food, we may see development of an active fishery for the species. Such a development would then remove the dogfish from the pest classification.

SUMMARY

The spiny dogfish, *Squalus acanthias*, is a small shark of the family Squalidae. It is extremely abundant locally and seasonally and has proved to be a costly nuisance to commercial fishermen in the United States.

It grows to a maximum length of 100-124 cm. and a maximum weight of 7.3-9.8 kg. The females usually are slightly larger than the males. Two sharp spines, one anterior to each dorsal fin, are the features that give the species its common name and serve to separate it readily from the smooth dogfish, *Mustelus canis*.

Although the spiny dogfish is distributed in many parts of the world, this report deals mostly with the groups found in the Northwest Atlantic. Pertinent information, however, is reported from studies of the species made in other areas.

The spiny dogfish usually is found in large schools composed of: (1) large, mature females; (2) medium-size-fish, either mature males or immature females; or (3) small, immature fish of both sexes in about equal numbers. The schools may spend considerable time in an area and then move rapidly from one area to another.

In the Northwest Atlantic they move from the southern part of their range, off North Carolina to New York, northward with the advance of the spring season. It is suspected they spend the winter offshore in deep water. In addition to the seasonal migrations, spiny dogfish take part in a daily migration, rising to or near the surface during the night and returning to the bottom during the day.

Tagging studies have had low rates of return compared with tagging studies of commercially valuable fishes. But the returns have shown that the spiny dogfish is capable of long-distance migrations—one individual travelled 4,700 miles—and is long-lived since several tagged fish were at liberty 7 to 10 years. In the New England area, the recaptures suggest that spiny dogfish school together for long periods of time and return to the same general area at about the same time of year.

Food habits studies show that spiny dogfish are primarily fish eaters but also feed on invertebrates, both swimming and bottom-dwelling forms. Clupeoids, smelts, and chimeroids were the fishes found most frequently in dogfish stomachs. They also feed on shrimp, crabs, and squids and are one of the few fishes that eat ctenophores. In general, they are considered opportunistic feeders, preying on whatever is abundant and readily available to them.

Age and growth studies based on interpretation of annulations on the dorsal spines suggest the spiny dogfish is long-lived with some individuals attaining ages of 20 to 30 years. Based on the spine readings, the growth rate is about $3\frac{1}{2}$ cm. per year. Growth of tagged dogfish, however, is less, usually about $1\frac{1}{2}$ cm. per year. At a given length, female dogfish are slightly heavier than male dogfish; mature and pregnant females are the heaviest and longest individuals.

It is difficult to make any analyses of the dynamics of dogfish populations because so much of the basic life history information is lacking. More is

known about the natality of the species than about the mortality.

The spiny dogfish is ovoviviparous. Sex ratio of the developing fetuses is very nearly 1:1, and presumably the young are born in the same ratio. Sex ratio of the older fish varies with the sexual maturity of the individuals; in general they tend to group themselves by sex. Sexual maturity is attained by males at 80–100 cm. in length and by females at 100–124 cm.

Mating takes place during the cold months, probably on the wintering grounds, and the young are born after a 2-year development. The number of young born per female varies with location. In the Pacific it averages about 11 in the western part and about 7 in the eastern part. In the Atlantic it averages about 4 in the western part and about 3 in the eastern part. At the time of birth the young dogfish are about 20–30 cm. long.

The natural mortality of the adults apparently is low. In the Western Atlantic their principal predators are the large sharks and large bony fishes. Records of cannibalism are rare, and there are few records of marine mammals feeding on spiny dogfish. Fishing mortality, however, takes a relatively high toll.

In the United States the spiny dogfish has been exploited mostly as an industrial fish for reduction to meal and oil. Immediately preceding and during World War II, the groups on the west coast were heavily exploited for their livers, an important source of natural vitamin A. At the peak of the fishery, in 1944, more than 40 million pounds of dogfish were taken from Puget Sound. The fishery collapsed when vitamin A was synthesized in 1947, and today about 2 million pounds are landed yearly. Most dogfish are caught with otter trawls or gill nets.

There is a small and relatively steady market in the United States for dogfish as human food. Technological problems, however, have prevented it from becoming more than just locally popular. Fresh dogfish fillets have a flavor and texture somewhat resembling those of haddock. It is a popular food fish in parts of Europe.

Management of the species is indicated to reduce the damage it causes to more valuable commercial fisheries. Finding an economically attractive use for the dogfish would be the most worthwhile management method. Lacking this,

perhaps some form of biological control must be instituted. However, more detailed information is needed about the life history and biology of the spiny dogfish before any management plan can be drawn up.

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PYGMY WHITEFISH *PROSOPIMUM COULTERI* IN THE NAKNEK RIVER SYSTEM OF SOUTHWEST ALASKA

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ABSTRACT

The pygmy whitefish is widely distributed throughout the lakes of the Naknek River system in southwest Alaska. It is a small abundant species in some lakes of the system and may occupy a more prominent place in the population dynamics of fishes in the Naknek system than in other geographic areas where it has been studied. Specimens were collected with a variety of sampling gear including gill nets, tow nets, otter trawls, and seines. Pygmy whitefish occurred in all benthic habitats from shallow littoral depths to bathybenthic areas. Seasonally in certain age groups and in certain areas they occurred in limnetic areas of lakes and in streams. In the Naknek system, 18 species, including the young of commercially valuable sockeye salmon and the closely related round whitefish, were ecological associates of pygmy whitefish.

Two populations, one in South Bay of Naknek Lake and the other in Brooks Lake, were studied in detail. The oldest and largest pygmy whitefish collected was an age V 163-mm. female from South Bay. An age III 83-mm. female was the oldest and longest specimen from Brooks Lake. Length frequency distributions from other lakes were intermediate between these extremes. Growth rates were back calculated from polynomial body length-scale length equations for Brooks Lake and South Bay populations.

Pygmy whitefish, *Prosopium coulteri* (Eigenmann and Eigenmann), are widely distributed throughout lakes of the Naknek River system in southwest Alaska (fig. 1). These lakes, which are important fresh-water rearing areas for juvenile sockeye salmon, *Oncorhynchus nerka* (Walbaum), are studied by the Bureau of Commercial Fish-

Dipteran insects were the principal foods eaten by pygmy whitefish in South Bay. Crustacean plankton dominated their diet in Brooks Lake. In other areas insects and zooplankton were about equal in importance. Growth and insect consumption were correlated positively.

Spawning occurs in November and December, apparently only at night. South Bay fish spawn in lower Brooks River. Eggs in ripe females from South Bay averaged 2.4 mm. in diameter, and the ovaries were 16.5 percent of the body weight. The fork length-fecundity relation of Naknek system pygmy whitefish has the equation

$$\text{Log } E = -2.9552 + 2.7513 \text{ Log } L$$

Both sexes mature earlier in Brooks Lake than in South Bay.

Slow growth, low fecundity, and short life characterize pygmy whitefish in Brooks Lake. These factors are compensated for in part by early maturity and probably by a low mortality from fertilized egg to maturity. The wide range of pygmy whitefish populations in the Naknek system probably reflects adaptive responses of a highly plastic species to the wide variety of environmental characteristics found in different lakes of the system.

eries to determine factors limiting fresh-water production of this highly important commercial species. These studies embrace a variety of limnological and biological research, including interspecific relations of fishes associated with juvenile salmon.

Pygmy whitefish are apparently the most abundant species in some lakes of the Naknek system, and it is possible that they may compete directly

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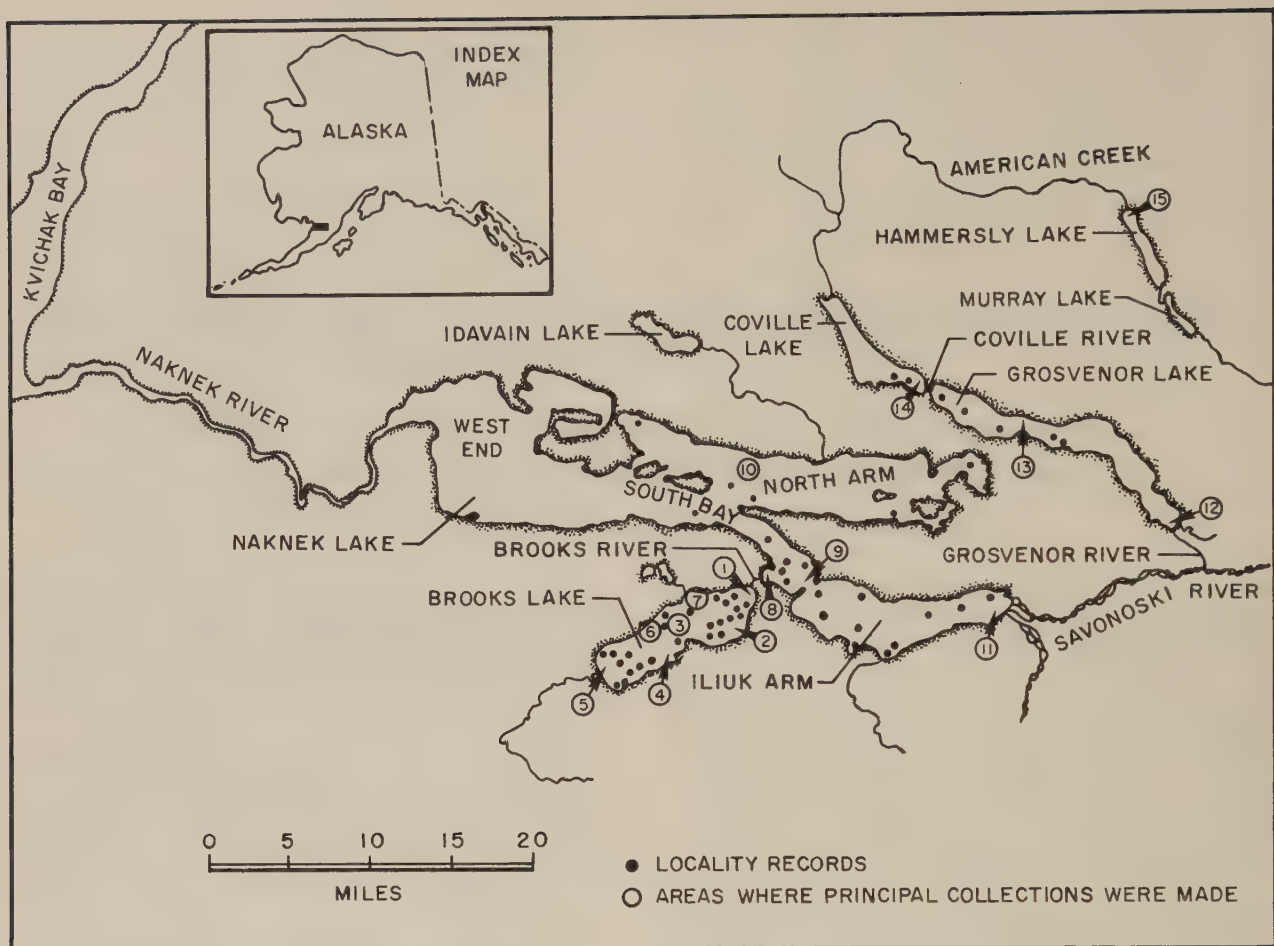


FIGURE 1.—Naknek River system of southwest Alaska, showing areas where pygmy whitefish were collected. Dots represent locality records; circled numbers are locations where 10 or more pygmy whitefish were collected in a specific sampling effort.

or indirectly with juvenile sockeye salmon for food or space. Other fishes, for instance the threespine stickleback (*Gasterosteus aculeatus*), have also been characterized as actual or potential competitors with juvenile sockeye salmon (Krogius and Krokhin, 1948; Greenbank and Nelson, 1959; and Burgner, 1960). Pygmy whitefish may also act as a buffer between salmon predators and young salmon.

There is relatively little literature concerning pygmy whitefish, and specific studies on the biology of this species are few. They were discovered in British Columbia in 1892 and were first collected in Alaskan waters in 1912 (Kendall, 1917). Although locality and life history data accumulated for several years (Snyder, 1917; Kendall, 1921; Schultz, 1941; and Wynne-Edwards, 1947

and 1952), published material was based on few specimens. Meyers (1932) reported on 21 specimens from Chignik River on the Alaska Peninsula, and Weisel and Dillon (1954) reported on 23 pygmy whitefish from western Montana. Eschmeyer and Bailey (1955) collected 1,623 pygmy whitefish from Lake Superior during a 2-year study and reported the discovery of a relatively large population in the lake and described its morphology and life history. Comparisons were made with previous collections from the Pacific slope. McCart (1963) has recently studied the growth and morphology of pygmy whitefish from several British Columbia lakes.

Pygmy whitefish were first collected in the Naknek River system at Brooks Lake in 1957, and observations in Brooks Lake have continued since

then.¹ Beginning in 1961 and continuing through 1963, observations were extended throughout the Naknek system. More than 10,000 specimens have been collected by various methods since 1961.

The present study was undertaken to investigate the distribution, age and growth, food habits, reproduction, and general life history of pygmy whitefish in the Naknek system. Emphasis was placed on determining the relation of pygmy whitefish biology to that of other fishes in the system, particularly the sockeye salmon.

STUDY AREA

The Naknek River system, much of which lies within Katmai National Monument, consists of seven interconnecting lakes: Hammersly, Murray, Coville, Grosvenor, Brooks, Idavain, and Naknek. These lakes drain into the northeast side of Bristol Bay through the Naknek River (fig. 1). All are glacial in origin, dating from Wisconsin times (Muller, 1952; and Karlstrom, 1957). Naknek Lake comprises three major basins and a shallow outwash plain. The basins, Iliuk Arm, North Arm, and South Bay, and the outwash plain, West End, will be referred to hereafter without reference to Naknek Lake. The maximum depths are not known for Murray, Idavain, or Hammersly Lakes. The other lakes vary between a maximum depth of 53 m. in Coville Lake and 173 m. in Iliuk Arm.

The lakes and basins of the Naknek system include a broad range of environmental types. Most of them are oligotrophic and usually have ice cover from December through early May. Iliuk Arm frequently does not freeze over completely, probably because of its depth and excessive turbidity, which is due to glacial melt water and volcanic ash. In Iliuk Arm, Secchi disk visibility is generally less than 0.5 m., while in the other basins and lakes it ranges between 3 and 12 m. A horizontal turbidity gradient occurs in South Bay, increasing in intensity toward Iliuk Arm. Thermal gradients commonly exist, although classical thermoclines develop only occasionally and are unstable. The waters are slightly alkaline, and oxygen levels remain at or near saturation at all depths measured throughout the year. The basic

limnology of lakes in the Naknek River system is described in detail elsewhere.²

MATERIALS AND METHODS

Most pygmy whitefish were collected in the Naknek system with small otter trawls, tow nets, beach seines, and small-meshed gill nets. A few specimens were collected with fyke nets and floating lake traps and by divers using hand nets. These same methods were used to sample juvenile sockeye salmon in various stages of their freshwater life. Heard (1962) described the small-meshed gill nets, and the three other principal types of gear are described below. All mesh sizes are given in stretch measure.

The otter trawls were Gulf Coast shrimp trawls about 6 m. long, 2.6 m. wide, and 0.6 m. deep. The cotton webbing varied from 50.8-mm. mesh in the front section to 25.4-mm. in the cod section, with a 13-mm. mesh cod liner. The foot-rope was weighted with a 19-mm. mesh chain, and the otter doors were 30.5 by 45.7 cm. Except for use of a tow cable guide ring on the transom, our use of these trawls behind an outboard skiff was basically the same as described by Baldwin (1961).

Trawl drags varied in time, in length of drag, and in depth. Generally they were between 8 and 15 minutes long and covered from 325 to 1,000 m. The trawls were fished effectively for pygmy whitefish to depths of 79 m.

The tow nets were 3.1 m. in diameter and 6.9 m. long, and they were used generally at night in limnetic (offshore or open water) portions of the lakes. They were towed behind two outboard skiffs with the top of the net at the surface or 3.1 m. deep. A standard tow was 492 m. Mesh sizes of nylon webbing varied from 38 mm. at the net opening to 3 mm. in the cod end. Burgner (1960) describes the construction and general use of this net. A 1-m. tow net such as that described by Johnson (1956) was used to collect one sample of pygmy whitefish in Brooks Lake.

Three types of beach seines were used. The two principal types, which were set in a semicircular pattern from shore with an outboard skiff, were 3.1 m. deep and 32.8 or 42.6 m. long. The 32.8-m. seine consisted solely of 3 mm. webbing, and the

¹ The annual field reports of the research operations at Brooks Lake (1957-62) are on file at the Bureau of Commercial Fisheries Biological Laboratory, Auke Bay, Alaska.

² Hartman, Wilbur L., and Robert L. Burgner. The limnology of sockeye salmon nursery lakes in southwest Alaska. The manuscript is filed in the U.S. Bureau of Commercial Fisheries Biological Laboratory, Auke Bay, Alaska.

42.6-m. seine consisted of a center section (9.8 m. long) of 6-mm. webbing and two end sections (16.4 m. long) of 12-mm. webbing. The third type was 1 m. deep with 3-mm. webbing and was either 3.1 or 6.1 long.

Most collections of pygmy whitefish were preserved and processed for various biological data; specimens from the other collections were discarded after the catch was recorded. Fork lengths were measured in millimeters and weights in tenths of grams. Most collections were preserved in 10-percent formalin for at least 48 hours before processing. The conversion factor of 0.977 to account for shrinkage was applied to length data on one group of fresh specimens. All lengths given are preserved lengths or equivalents. Because Eschmeyer and Bailey (1955) presented their pygmy whitefish data in total lengths, we determined factors for converting fork lengths to total lengths. Fork length times 1.0777 equals total length for specimens shorter than 100 mm., and fork length times 1.0845 equals total length for specimens longer than 100 mm.

Biological information determined from individual specimens included age and growth determinations, stomach content analyses, and reproductive data. Age and growth were analyzed from scale samples and length frequencies. Stomach content analyses were made either on all of the specimens or on random samples from different collections. The occurrence of food items was determined for individual fish, while volumetric analyses were made by combining food items from all fish in a specific collection. Sex ratios and age and length at maturity were determined for random samples or for all fish in different collections. Egg content was determined for 85 females by total count.

DISTRIBUTION AND ABUNDANCE OF PYGMY WHITEFISH

Pygmy whitefish have the greatest discontinuous range of any fresh-water fish in North America according to Eschmeyer and Bailey (1955). In addition to its occurrence in Lake Superior of the Atlantic slope, this species has been recorded from the Columbia River drainage in Washington, Montana, and British Columbia (Schultz, 1936; Weisel and Dillon, 1954) and from the Fraser, Skeena, Yukon, and Mackenzie River systems of

the Pacific and Arctic slopes (Carl, Clemens, and Lindsey, 1959). It also occurs in both Pacific and Bering Sea drainages of southwest Alaska, having been reported from the Nushagak (Snyder, 1917), Chignik (Kendall, 1917), Naknek (Merrell, 1964), and Kvichak (personal communication, Ole A. Mathisen and O. E. Kerns) River systems. Pygmy whitefish probably occur in other Bristol Bay river systems on the Alaska Peninsula, such as the Ugashik and Egegik, where large lakes appear to provide suitable habitat.

Eschmeyer and Bailey (1955) concluded that the present disjunct populations of pygmy whitefish are all referable to the same species and most likely represent relicts of a continuously distributed species in late Pleistocene that survived in deep lakes after the retreat of Wisconsin glaciation. McCart (1963) compared meristic and morphological variation in pygmy whitefish from British Columbia with those from other areas and found the species to be highly variable both within and between populations.

The sizes attained by pygmy whitefish in different geographic areas varied, most likely because of differences in growth rates related to different environments. The maximum size reported from Lake Superior was 149 mm. Carl, Clemens, and Lindsey (1959) reported a population of "giant" pygmy whitefish in Maclure Lake, British Columbia. McCart (1963) found pygmy whitefish in this lake as large as 262 mm. The maximum sizes in the Naknek system varied considerably between lakes, ranging from 84 mm. in Brooks Lake to 163 mm. in South Bay (fig. 2).

NAKNEK SYSTEM

Pygmy whitefish are widely distributed throughout the Naknek system and were collected in every major water area in the system except Idavain and Murray Lakes and West End (table 1). No attempt was made to collect them in Idavain Lake, and only one small-meshed gill-net set, which was unproductive, was made in Murray Lake. Pygmy whitefish may have been collected in 1962 from the West End in tow nets, but the discarded specimens were recorded on field data sheets only as "whitefish." It is likely that they do occur in these three major areas, however.

The abundance of pygmy whitefish varied throughout the system. The distribution is best

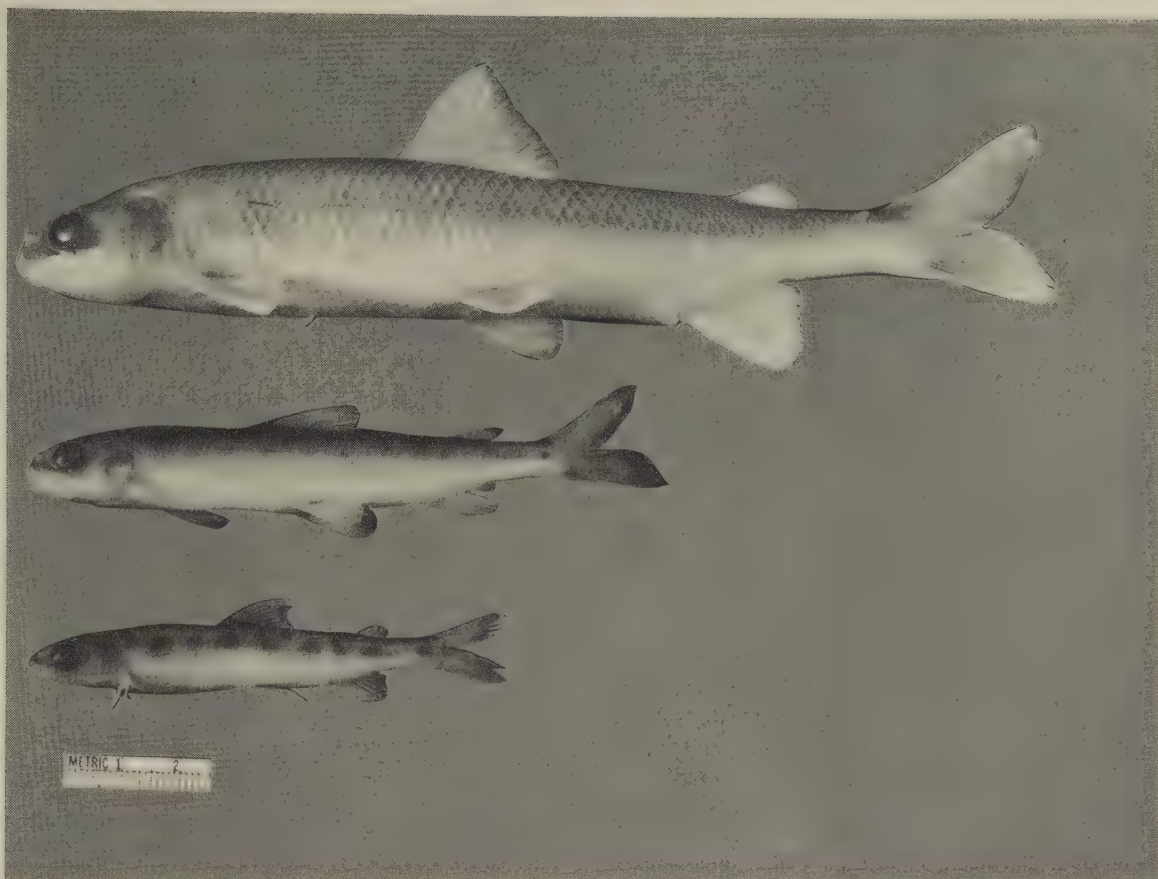


FIGURE 2.—Pygmy whitefish from the Naknek system. From top to bottom: 5-year-old mature female, 163 mm. long, collected November 9, 1962, in South Bay; 3-year-old mature female, 76 mm. long, collected November 9, 1962, in South Bay; 2-year-

old immature female, 98 mm. long, collected November 9, 1962, in South Bay; 3-year-old mature female, 76 mm. long, collected November 7, 1962, from Brooks Lake.

known in Brooks Lake where the greatest sampling effort was expended. Pygmy whitefish were collected in all sections of Brooks Lake, and two areas of heavy abundance were found at opposite ends of the lake (areas 1 and 5 (fig. 1)). They also occurred throughout South Bay and Iliuk Arm. A concentration of this fish apparently occurs in the semiprotected bay of South Bay near the mouth of Brooks River and in the upper end of Iliuk Arm. The known distribution of pygmy whitefish in North Arm is spotty, but it is believed to be widely distributed in this basin. In 1962 and 1963, small whitefish were not specifically identified on field collection sheets of seine records from that basin. We suspect that at least some of these were pygmy whitefish. In Grosvenor Lake, pygmy whitefish were collected in most areas of the lake; but, in Coville Lake, they were collected only from the east end of the lake. The one Hammersly Lake

collection was made near the lake outlet.

The most widely used sampling gear throughout the system was tow nets, which was used in open-water limnetic areas, primarily to sample juvenile sockeye salmon. Otter trawls, gill nets, and seines, which were more effective than tow nets in sampling pygmy whitefish, were used to different degrees in different areas (table 1). The unknown vulnerability of pygmy whitefish to different types of gear and the unequal use of each type in various lakes and basins should be kept in mind when considering relative abundance.

On the basis of the number of specimens obtained in other geographic areas by previous collectors, populations of pygmy whitefish may occupy a more dominant role in the overall fish population structure in parts of the Naknek system than in other areas. In the Lake Superior study, the greatest single collection of pygmy

TABLE 1.—Sampling efforts ¹ with otter trawls, tow nets, small-meshed gill nets, and beach seines in Naknek system and percent of samples yielding pygmy whitefish, 1961-63

Sampling area and year	Otter trawl		Tow net		Gill net ²		Seine	
	Sampling efforts	Samples with pygmy whitefish	Sampling efforts	Samples with pygmy whitefish	Sampling efforts	Samples with pygmy whitefish	Sampling efforts	Samples with pygmy whitefish
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Brooks Lake:								
1961	79	33	108	31			3	33
1962	60	43	154	8	2	100	28	36
1963	4	75	40	8	9	78	4	75
Coville Lake:								
1961			60	0			5	³ 0
1962	15	0	41	2	1	100	37	³ 24
1963	5	0	47	2	3	0		
Grosvenor Lake:								
1961			101	3			7	³ 0
1962	21	10	53	4			26	³ 12
1963	1	100	20	5				
Naknek Lake:								
South Bay:								
1961	1	100	57	4			6	33
1962	8	75	61	10	3	100	47	68
1963	2	100	39	3	6	100	6	83
Iliuk Arm:								
1961	2	0	49	2	2	100	4	50
1962			72	6			12	58
1963			36	6	2	50	2	100
North Arm:								
1961			32	0	3	100	8	0
1962			94	1	3	100	24	³ 0
1963			12	0	1	100	5	0
West End:								
1961	5	0	21	0				
1962			52	³ 0			5	0
1963			44	0				
Hammersly Lake:								
1962					1	100		
Murray Lake:								
1962					1	0		
Brooks River:								
1963	4	100					2	100

¹ A sampling effort equals one trawl haul, tow net haul, gill net lift, or individual seine haul.

² Includes only those gill net sets with mesh sizes 1-inch stretch measure or smaller.

³ Not including sampling efforts containing unidentified small whitefishes which may have included pygmy whitefish.

whitefish was 171 specimens taken in an otter trawl in Siskiwit Bay (Eschmeyer and Bailey, 1955). Our largest single collection was 1,701 specimens taken in a beach seine haul on August 14, 1962, in Brooks Lake (table 2). The largest Lake Superior collection had about 80 percent age 0+ fish, while the largest Brooks Lake collection had 100 percent age 0+ fish. Our second largest collection was made July 10, 1962, by a trawl drag in Brooks Lake that yielded 1,567 age I+ and age II+ fish. A beach-seine haul in South Bay on August 4, 1962, yielded 964 specimens (table 2). Of these, 962 were age I+ and older. All of the 1961-63 collections of pygmy whitefish from the Naknek system in which 10 or more specimens were caught in a sampling effort are listed by date, area, gear, depth, and number of specimens in table 2.

ECOLOGICAL AND SEASONAL DISTRIBUTION

Pygmy whitefish occupy a wide variety of ecological habitats in the Naknek system. They were caught not only in benthic habitats, ranging from

a depth of 168 m. (in Iliuk Arm and North Arm) to littoral areas less than 1 m. deep, but also in limnetic areas at or near the surface over deep water and in several streams.

The capture of pygmy whitefish in littoral areas with seines and trawls and in limnetic areas with tow nets was somewhat unexpected. In Lake Superior, Eschmeyer and Bailey (1955) caught pygmy whitefish only in benthic areas below 10 fathoms. Except for six specimens caught in gill nets, all Lake Superior pygmy whitefish were caught in otter trawls.

Most littoral catches of pygmy whitefish in the Naknek system were made at the northeast end of Brooks Lake and in a semiprotected bay in South Bay (areas 1 and 8, fig. 1). Part of this littoral area in Brooks Lake consisted of a shallow sandy shelf 1 to 2 m. deep that extended 300 to 500 m. into the lake. This shelf is subject to heavy wave action and is barren of vegetation except for small patches of *Ranunculus* sp. Large schools of age 0+ pygmy whitefish were observed by biologists

TABLE 2.—Collections of pygmy whitefish from the Naknek system in which 10 or more specimens were caught per sampling effort¹ by area, gear, depth, and number of specimens, 1961–63

Sampling area and date	Numbered area ²	Type of gear	Depth	Total specimens caught	Sampling area and date	Numbered area ²	Type of gear	Depth	Total specimens caught
			Meters	Number				Meters	Number
Brooks Lake:					South Bay—Con.				
July 17, 1961	1	Otter trawl	8	290	July 23, 1962	9	Seine	3	16
July 18, 1961	7	do	12	11	July 23, 1962	9	do	3	25
July 20, 1961	1	do	2	89	July 23, 1962	9	do	3	16
July 21, 1961	2	do	3	32	July 23, 1962	9	do	3	53
Aug. 7, 1961	4	do	5	150	July 23, 1962	9	do	3	10
Aug. 8, 1961	5	do	5	308	Aug. 4, 1962	8	do	2	542
Aug. 8, 1961	5	do	8	344	Aug. 4, 1962	8	do	2	16
Aug. 10, 1961	5	do	15	12	Aug. 4, 1962	8	do	2	22
Aug. 10, 1961	5	do	32	10	Aug. 4, 1962	8	do	2	345
Aug. 11, 1961	1	Tow net (3.1 m.)	0–3.1	16	Aug. 4, 1962	8	do	2	11
Aug. 11, 1961	2	do	0–3.1	321	Aug. 4, 1962	8	do	2	964
Sept. 1, 1961	1	do	0–3.1	10	Aug. 24, 1962	8	do	2	96
Sept. 14, 1961	1	Otter trawl	5	96	Sept. 26, 1962	8	do	2	148
Sept. 26, 1961	6	Tow net (3.1 m.)	3.1–6.1	10	Nov. 9, 1962	8	do	2	124
June 29, 1962	1	Otter trawl	4	70	Nov. 10, 1962	8	Gill net	8	116
June 29, 1962	1	do	10	425	Apr. 16, 1963	8	do	7	20
July 10, 1962	1	do	8	1,567	May 30, 1963	8	do	8	12
July 11, 1962	5	do	2	88	June 14, 1963	8	Seine	1	12
July 22, 1962	1	do	8	18	July 11, 1963	8	do	1	144
July 22, 1962	1	do	8	46	Oct. 29, 1963	8	Gill net	8	33
July 23, 1962	7	Tow net (1-m.)	0–1	168	Nov. 5, 1963	8	do	8	56
July 26, 1962	1	Otter trawl	5	40	Dec. 12, 1963	8	do	3	81
July 27, 1962	2	do	3	69	Brooks River:				
Aug. 10, 1962	4	Seine	2	24	July 27, 1963	8	Seine	1	458
Aug. 10, 1962	5	do	2	88	Aug. 24, 1963	8	Otter trawl	1	178
Aug. 10, 1962	5	do	2	15	Aug. 24, 1963	8	do	1	18
Aug. 10, 1962	5	do	2	16	Aug. 25, 1963	8	do	1	200
Aug. 14, 1962	1	do	1	1,701	Aug. 25, 1963	8	do	1	150
Sept. 14, 1962	1	Otter trawl	8	15	Iliuk Arm:				
Nov. 7, 1962	1	do	8	306	July 9, 1963	11	Seine	3	12
Nov. 8, 1962	1	Gill net	12	67	July 27, 1963	11	do	3	27
Nov. 8, 1962	2	do	3	11	North Arm:				
July 2, 1963	1	Hand net	1	17	July 22, 1962	10	Gill net	169	10
July 8, 1963	1	Seine	1	65	Aug. 9, 1962	10	do	169	21
July 16, 1963	1	do	1	17	Coville Lake:				
July 22, 1963	3	Gill net	66	14	June 7, 1962	14	Seine	2	12
July 22, 1963	3	Otter trawl	65	10	June 7, 1962	14	do	2	10
July 26, 1963	3	Gill net	78	10	June 9, 1962	14	do	2	10
Aug. 7, 1963	1	Seine	1	18	July 12, 1962	14	do	2	12
Aug. 9, 1963	3	Gill net	78	18	Grosvenor Lake:				
Aug. 20, 1963	3	do	75	11	June 30, 1962	12	do	2	48
Dec. 16, 1963	1	do	12	29	Aug. 5, 1962	13	Otter trawl	8	54
South Bay:					Aug. 19, 1963	12	do	7	96
July 15, 1962	8	Seine	2	46	Hammersly Lake:				
July 22, 1962	9	do	3	36	Aug. 20, 1962	15	Gill net	20	12

¹ A sampling effort is an individual trawl haul, tow net haul, beach seine haul, or gill net lift.

² See figure 1.

³ Gill net was buoyed so that it was fishing horizontally 3 m. off the bottom in water 78 m. deep.

skin diving along this shelf during June, July, and August, 1962 and 1963. These fish were routinely caught with seines or hand nets. On July 23, 1962, 168 age 0+ pygmy whitefish were caught on the edge of this shelf in a 1-m. tow net (table 2). This particular catch was made in an area where Arctic Terns (*Sterna paradisaea*) were feeding on small fishes near the surface, presumably pygmy whitefish. Littoral collections in South Bay were made during April, May, June, July, August, September, October, November, and December in either 1962 or 1963 (table 2). Pygmy whitefish apparently remain in the littoral area of this bay throughout most of the year. No sampling was attempted during late winter or early spring.

In addition to the above areas, substantial numbers of pygmy whitefish were also caught in littoral areas in the narrows between South Bay and Iliuk Arm, at the upper end of Iliuk Arm, and

near the outlets of Grosvenor and Coville Lakes (areas 9, 11, 12, and 14, fig. 1).

Pygmy whitefish in the Naknek system apparently are associated with the benthic zone at all lake depths. Benthic collections have been made from all depths in Brooks Lake with seines, trawls, or gill nets and from shallow shoreline and the deepest areas of North Arm and Iliuk Arm with seines and gill nets. This distribution differs from the bathybenthic distribution found in Lake Superior (Eschmeyer and Bailey, 1955) and the intermediate benthic distribution found in four British Columbia lakes (McCart, 1963). In each of these studies, pygmy whitefish were sampled primarily with one collecting gear—trawls in Lake Superior and gill nets in British Columbia.

Although pygmy whitefish are generally associated with the benthic zone, concentrations of them were typically spotty. A series of 11 conse-

cutive seine hauls made along a 600-m. stretch of beach in South Bay on August 4, 1962 (table 3), shows that catches are variable and suggests that pygmy whitefish are frequently grouped in large schools. Approximately 80 percent of the pygmy whitefish collected throughout the Naknek system came from specific sampling efforts that yielded 100 or more specimens.

TABLE 3.—Age 0+ and older pygmy whitefish caught in 11 consecutive seine hauls in South Bay, August 4, 1962

Seine haul number	Fish per haul	
	Age 0+	Age 1+ and older
	Number	Number
1	0	542
2	1	0
3	1	3
4	2	3
5	12	4
6	20	2
7	0	0
8	0	0
9	4	341
10	7	3
11	2	962

Underwater observations on the schooling and feeding behavior in lower Brooks River indicated that pygmy whitefish are frequently grouped in schools of several thousand fish. Fishes in these schools were evenly spread out over several meters of stream bottom. Individuals fed independently of other fish, and the undisturbed school of fish would slowly move from one area to another. When disturbed by an observer or predator, schools of pygmy whitefish in Brooks River became tightly grouped.

The distribution of age 0+ pygmy whitefish, particularly in Brooks Lake, changes in late summer. Many of these young whitefish remain in littoral areas on the sandy shelf along the northeast shoreline of Brooks Lake throughout much of the summer, but by mid-August they begin disappearing. They are scarce in this area in September. During the same period, limnetic catches of pygmy whitefish in tow nets increase. Age 0+ sockeye salmon in Wood River Lakes behave similarly (Burgner, 1960). Naknek system age 0+ sockeye salmon also show this behavior, although it is not as pronounced. The reasons for this fall change in distribution of young pygmy whitefish are not known. The autumn lake turnover, changes in diet attendant with shifts in food supplies, or other limnological changes may be in-

volved. During the fall, weather on the Alaska Peninsula is characterized by severe storms with gale winds. The resultant heavy wave action may tend to disperse young pygmy whitefish from littoral areas.

About 95 percent of the pygmy whitefish caught with tow nets in all lakes and basins were age 0+ fish. In 1961 tow nets were used in Brooks Lake from mid-August throughout September, while otter trawls were used primarily from mid-July to mid-August. A comparison of length frequencies of pygmy whitefish caught in limnetic areas with tow nets with those caught in benthic areas with trawls during these periods indicates (fig. 3)

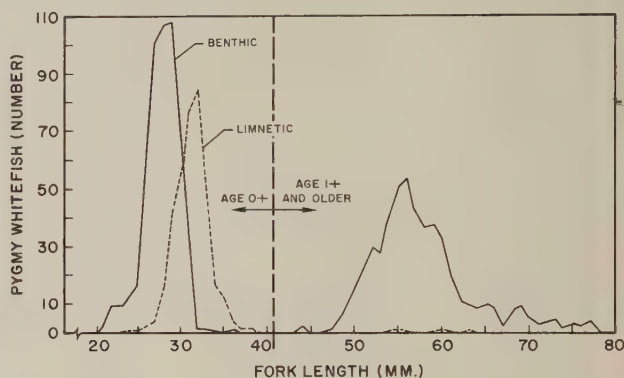


FIGURE 3.—Comparison of length frequencies of pygmy whitefish caught from mid-July to mid-August in benthic areas with otter trawls with those caught from mid-August through September in limnetic areas with 3.1-m.-diameter tow nets, Brooks Lake, 1961.

that while both age 0+ and older fish were caught in the benthic zone, most of those caught in the limnetic zone were age 0+. Differences in the selectivity of the two gears could have affected these catches; however, we do not feel trawls were selectively collecting older, larger pygmy whitefish since comparative catches of other fishes suggest that larger specimens are usually caught in tow nets. Our interpretation of these data is that fewer age 1+ and older pygmy whitefish were present in limnetic areas than in benthic areas. Differences in length frequencies of age 0+ fish shown in figure 3 are due to sampling periods and not to differences in size of fish caught in separate ecological areas or with different sampling gear. In 1962 and 1963 when tow nets were used in Brooks Lake throughout July and August, no pygmy whitefish were caught in limnetic areas

until late August. Some age 0+ fish may have been present in limnetic areas before this time, although they probably would have been too small to capture in the available gear. Few tow net hauls were made in September, except in Brooks Lake in 1961.

Although no permanent stream populations of pygmy whitefish are known to exist in the Naknek system, large numbers seasonally occupy the lower 100 to 400 m. of Brooks River. These fish are part of the South Bay population (area 8, fig. 1) and do not go above a rapids area below Brooks River falls. They occupy lower Brooks River from late June to early September for feeding and from mid-November to mid-December for spawning. Feeding pygmy whitefish in Brooks River characteristically occupy neither the fastest moving nor the slowest moving water, but seem to prefer a moderate current adjacent to a faster one.

A few pygmy whitefish have been collected or observed in other streams in the system. With the possible exception of an annual downstream drift of spent fish in midwinter, these collections apparently represent only sporadic downstream movements of fish from Brooks, Coville, and Grosvenor Lakes. Underwater surveys of upper Brooks River from May through November and of Coville River from May through August revealed that pygmy whitefish did not occupy these streams during this period.

ASSOCIATED FISHES

Nineteen species of fishes were collected with pygmy whitefish in various parts of the system.

The percent frequency occurrence of these species (table 4) provides a basis for discussing associated species. Throughout the system the cottids *Cottus aleuticus* Gilbert and *C. cognatus* Richardson were the most frequent associates, occurring in 55 percent of all sampling efforts that yielded pygmy whitefish (table 4). Juvenile sockeye salmon were the second most frequent associates, occurring in 42 percent of the samples. Next in frequency of association with pygmy whitefish were ninespine sticklebacks, threespine sticklebacks, round whitefish, and least cisco (table 4). The greatest number of sympatric associates in a specific area was 17 species in South Bay.

Certain fishes in the Naknek system were not caught with pygmy whitefish in all lake areas. Least cisco, humpback whitefish, pond smelt, and longnose sucker, were collected widely in other parts of the system but not in Brooks Lake. Alaska blackfish, abundant in Brooks Lake, were not collected in South Bay or Iliuk Arm. Differences in sampling gear and effort may account for species not being caught in certain areas.

The two most common associates of pygmy whitefish in Lake Superior were cottids and nine-spine sticklebacks (Eschmeyer and Bailey, 1955). Round whitefish, which were never collected in association with pygmy whitefish in Lake Superior, occurred in 17 percent of the Naknek system samples yielding pygmy whitefish. These whitefishes were collected together in six of eight major lakes, basins, or streams (table 4). This apparent difference in association between pygmy whitefish and its closest relative in Lake Superior

TABLE 4.—Percent frequency occurrence of associated fishes in sampling efforts¹ that yielded pygmy whitefish

Species	Brooks Lake	South Bay	Iliuk Arm	North Arm	Coville Lake	Grosvenor Lake	Hammersly Lake	Brooks River	All areas combined
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Cottid, <i>Cottus</i> spp.	60	53	38	63	67	42	100	17	55
Sockeye salmon, <i>Oncorhynchus nerka</i> ²	35	41	71	25	67	58		33	42
Ninespine stickleback, <i>Pungitius pungitius</i> ..	39	36	10	62	25				33
Threespine stickleback, <i>Gasterosteus aculeatus</i> ..	29	24	38	38	92	17			31
Round whitefish, <i>Prosopium cylindraceum</i> ..	7	29	29	50		8		67	17
Least cisco, <i>Coregonus sardinella</i>		20	52	38				33	12
Alaska blackfish, <i>Dallia pectoralis</i>	18								9
Pond smelt, <i>Hypomesus olidus</i>		15	38		8				8
Arctic lamprey, <i>Lampetra japonica</i>	10	2							6
Lake trout, <i>Salvelinus namaycush</i>	1	3	14	38	8			100	4
Arctic grayling, <i>Thymallus arcticus</i>	2	11						17	4
Humpback whitefish, <i>Coregonus pidschian</i>		3	10	50					3
Coho salmon, <i>Oncorhynchus kisutch</i> ²	3	3		13				17	3
Arctic char, <i>Salvelinus alpinus</i>		5	5	25			100		3
Rainbow trout, <i>Salmo gairdneri</i>	2	3						100	2
Dolly Varden, <i>Salvelinus malma</i>		9							2
Longnose sucker, <i>Catostomus catostomus</i>		3	14	13					2
Northern pike, <i>Esox lucius</i>			14						1
Burbot, <i>Lota lota</i>		2							T

¹ Sampling efforts of all gears were combined for each area, then for all areas; see table 1 for total sampling effort by gear and area.

² Juveniles only.

and the Naknek system may be related to the use of only trawls in Lake Superior and several gears in the Naknek system. In the present study few round whitefish were captured in trawls. McCart (1963), using gill nets, found little or no association between pygmy whitefish and mountain whitefish *Prosopium williamsoni* (Girard) or lake whitefish *Coregonus clupeaformis* (Mitchill) in Cluculz and Tacheeda lakes, British Columbia.

AGE AND GROWTH

BODY-SCALE RELATION

The relation between body length and the anterior scale radius (mm. multiplied by 80) was determined for 456 pygmy whitefish from Brooks Lake and 500 from South Bay. Data from both lakes indicate this relation is highly sigmoid. Rounsefell and Everhart (1953, p. 324) suggest that problems of curvilinearity can be solved by omitting the earliest years and back calculating only those ages that do not deviate appreciably from linearity. The persistence of a curvilinear body-scale relation in the older age groups of Naknek system pygmy whitefish prevented any linear treatment of older fish. Also, these fish are relatively short lived, reaching a maximum age of 3 years in Brooks Lake and 5 years in South Bay. Age was determined from scale annuli, which, excluding scales from a few older fish, were not difficult to locate.

Fourth degree polynomial equations were found, excluding highly spurious intercepts, to fit fairly closely the empirical data for the body-scale relations of Brooks Lake and South Bay pygmy whitefish. These equations were calculated from individual pairs of body-scale observations. Mean body lengths for each scale radius are plotted against the calculated relations for both areas (figs. 4 and 5). Body length at scale formation is apparently between 22 and 27 mm. as determined by: (1) staining small fish for the first evidence of scale development and (2) calculating the intercept for collections of age 0+ fish after scale development. Separate equations were necessary for the Brooks Lake and South Bay collections because of strikingly different growth rates in the

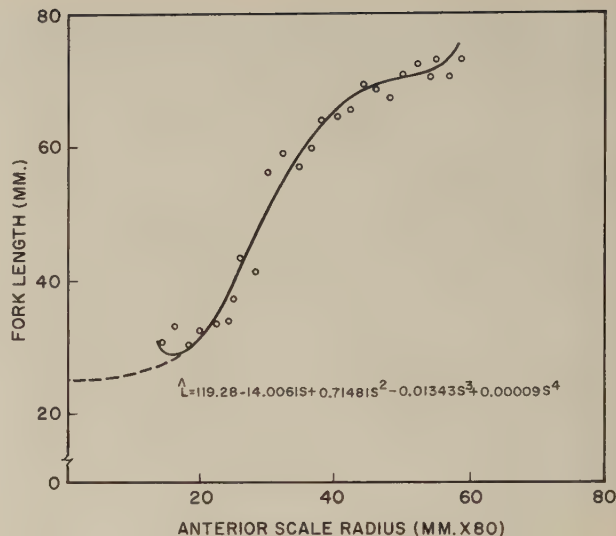


FIGURE 4.—Body length-scale radius relation of pygmy whitefish in Brooks Lake. Solid line is calculated equation; points represent mean body lengths for given scale radii; dashed line connects estimated intercept of 25 mm. with the logical portion of calculated curve.

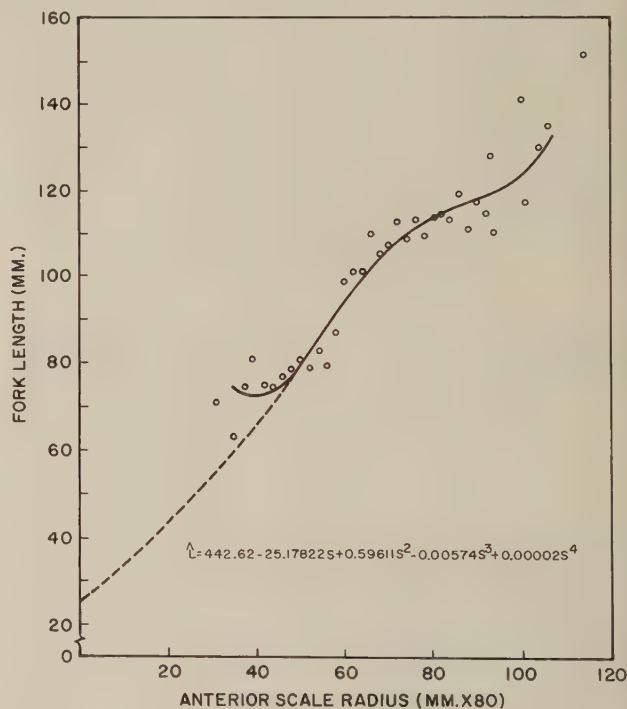


FIGURE 5.—Body length-scale radius relation of pygmy whitefish in South Bay. Solid line is calculated equation; points represent mean body lengths for given scale radii; dashed line connects estimated intercept of 25 mm. with the logical portion of calculated curve.

two populations.³ Growth rates were back calculated from these quartic equations.

CALCULATED GROWTH

Fork lengths attained at each year of life and the annual increments were calculated by sex for 330 pygmy whitefish from Brooks Lake (table 5) and 779 from South Bay (table 6). A comparison of these growth rates reveals that pygmy whitefish grew considerably faster in South Bay than in Brooks Lake. The largest pygmy whitefish collected from Brooks Lake was an 84-mm. mature female that had just completed its third growing season. Two slightly older (III+) but smaller, slower growing females were collected from Brooks Lake. In South Bay the largest and oldest pygmy whitefish was a 163-mm. age V mature female.

During their first year of life, males in Brooks Lake grew slightly faster than females. In subsequent years in Brooks Lake and in all years in Naknek Lake, females consistently grew at a faster rate than males (tables 5 and 6). Males in Lake Superior grew slightly faster than females during the first year, grew at about the same rate as females during the second year, and grew slower than females during later years. Male pygmy whitefish in Lake McDonald, Mont., grew faster in their first year but slower than females in subsequent years, while females in Bull Lake, Mont., grew faster in all years (Eschmeyer and Bailey, 1955). With minor variations, these growth patterns are similar to those reported by McCart (1963) for pygmy whitefish in MacLure, McLeese, Cluculz, and Tacheeda Lakes, British Columbia. Males grew at about the same rate as females for the first 2 years, after which females consistently grew faster than males.

³ Additional study is needed to understand fully the curvilinear body-scale relation of these whitefish. Few specimens have been collected from South Bay as small as the age I and II fish from Brooks Lake with usable scales. Obviously the calculated curve for South Bay fish below 75 mm. is not biologically valid. With adequate data the lower portion of the South Bay curve could approach the Brooks Lake curve for the same size fish, in which case a single equation might express the body-scale relation for both populations. The problem is aggravated by the ease with which small pygmy whitefish lose their relatively large scales. Also, South Bay fish grow as large in 1 year as Brooks Lake fish do in 2 years, and it is not known what effect different growth rates between populations or between year classes within the same population have on body-scale relation curvilinearity.

TABLE 5.—Average fork length at time of capture and calculated length at end of each year of life for pygmy whitefish collected in Brooks Lake during summer and fall 1962

Age group	Sex	Fish in sample	Fork length at capture	Calculated fork length at end of year of life		
				1	2	3
		Number	Mm.	Mm.	Mm.	Mm.
I.....	Male.....	80	57.2	42.4	-----	-----
	Female.....	70	57.2	42.4	-----	-----
II.....	Male.....	32	63.9	41.0	61.3	-----
	Female.....	134	69.6	41.7	65.2	-----
III.....	Male.....	2	70.5	41.9	66.1	68.9
	Female.....	12	74.5	35.6	64.2	71.3
Grand average.....	Male.....	-----	-----	42.0	61.6	68.9
	Female.....	-----	-----	41.6	65.1	71.3
Average increment.....	Male.....	-----	-----	42.0	19.6	7.3
	Female.....	-----	-----	41.6	23.5	6.2
Number of fish.....	Male.....	114	-----	114	34	2
	Female.....	216	-----	216	146	12

TABLE 6.—Average fork length at time of capture and calculated length at end of each year of life for pygmy whitefish collected in South Bay during summer and fall 1962

Age group	Sex	Fish in sample	Fork length at capture	Calculated fork length at end of year of life				
				1	2	3	4	5
		No.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.
I.....	Male.....	161	77.0	61.5	-----	-----	-----	-----
	Female.....	175	76.2	60.6	-----	-----	-----	-----
II.....	Male.....	214	108.6	62.8	100.7	-----	-----	-----
	Female.....	181	112.4	64.7	103.3	-----	-----	-----
III.....	Male.....	14	117.6	65.0	98.9	114.1	-----	-----
	Female.....	16	127.1	64.1	99.6	116.2	-----	-----
IV.....	Male.....	4	132.5	64.0	103.3	116.6	119.9	-----
	Female.....	12	138.2	64.2	103.8	118.0	129.1	-----
V.....	Male.....	0	-----	-----	-----	-----	-----	-----
	Female.....	2	155.0	59.0	82.4	117.5	125.7	135.8
Grand average.....	Male.....	-----	-----	62.4	100.6	114.6	119.9	-----
	Female.....	-----	-----	62.8	102.8	117.0	128.6	135.8
Average increment.....	Male.....	-----	-----	62.4	38.2	14.0	5.3	-----
	Female.....	-----	-----	62.8	40.0	14.2	11.6	7.2
Number of fish.....	Male.....	393	-----	393	232	18	4	-----
	Female.....	386	-----	386	211	30	14	2

The annual growth of female pygmy whitefish from Lake Superior (Keweenaw and Siskiwit Bays), Mich., and Bull Lake and Lake McDonald, Mont., when compared with growth of females from Brooks Lake and South Bay (fig. 6), revealed that the slow growth in Brooks Lake was similar to that in Lake Superior, while growth in South Bay was intermediate between growth in Bull Lake and Lake McDonald. Comparisons of annual growth rates of female pygmy whitefish from the Naknek system with those from MacLure, McLeese, Cluculz, and Tacheeda Lakes (McCart, 1963) indicate (fig. 6) that growth in South Bay was intermediate between growth in McLeese and Cluculz Lakes, while growth in Brooks Lake was slower than in any of the British Columbia lakes. The length attained by pygmy white-

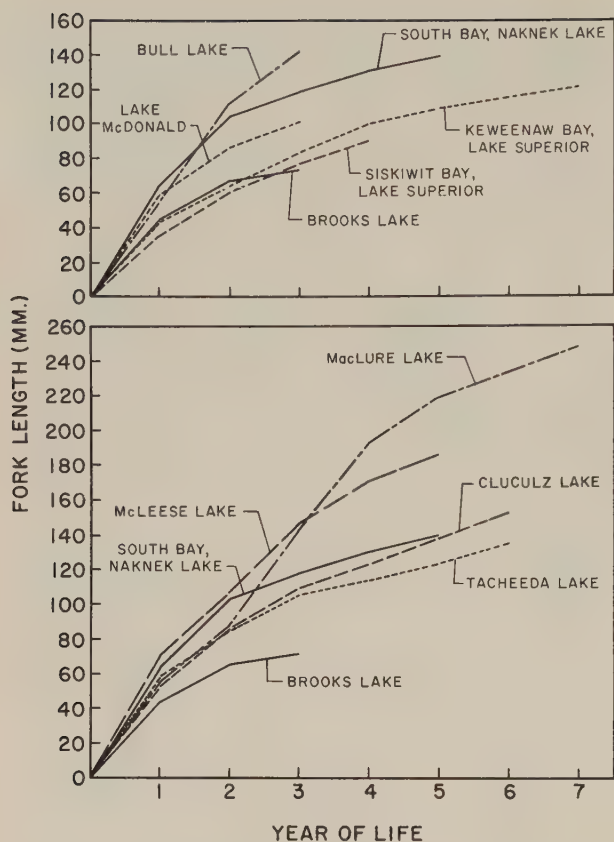


FIGURE 6.—Calculated growth of female pygmy whitefish from Brooks Lake and South Bay, Naknek River system, compared with data from Lake Superior, Mich., and Lake McDonald and Bull Lake, Mont., (Eschmeyer and Bailey, 1955) and MacLure, McLeese, Cluculz, and Tacheeda Lakes, British Columbia (McCart, 1963). Data from Eschmeyer and Bailey were converted from total to fork length.

fish in MacLure Lake is by far the greatest known for this species.

EMPIRICAL GROWTH

Although the average annual growth was not calculated for all lakes in the Naknek system, length frequency distributions of collections from six areas (table 7) provide a basis for growth comparison. The broad range of length frequencies suggests differences in growth rates that reflect the ecological differences in various lakes and basins in the system. The oldest pygmy whitefish collected from Grosvenor Lake, Hammersly Lake, and North Arm were age III+ females 95, 96, and 100 mm.⁴ long, suggesting growth rates intermediate between those from Brooks Lake and

South Bay. In Iliuk Arm the length of the largest pygmy whitefish, a 132-mm. age IV+ female, is comparable with the average calculated length of the same age fish in South Bay.

The striking difference in growth of pygmy whitefish in Brooks Lake and South Bay is apparent during the first summer. The earliest collections of age 0+ pygmy whitefish were made there in late June and early July. In early July, age 0+ pygmy whitefish were about equal in length in the two areas, averaging between 20 and 23 mm. long. By late August, however, age 0+ pygmy whitefish from South Bay were almost 10 mm. longer than fish from Brooks Lake (fig. 7). Based on the average calculated growth rates, South Bay pygmy whitefish are about 20 mm. longer than Brooks Lake fish at the end of the first growing season (fig. 6). There was little difference in the lengths of age 0+ fish taken in mid-July from Brooks River, North Arm, South Bay, and Brooks Lake. A sample of age 0+ pygmy whitefish from Grosvenor Lake in mid-August indicated an average length similar to that in Brooks Lake in mid-August.

An interesting comparison of the first year growth of pygmy whitefish with that of its close relative, round whitefish (fig. 8), indicates that age 0+ samples of both species collected in the same seine haul from Brooks Lake on August 10, 1962, had no overlap in lengths and round whitefish were considerably larger.

FOOD HABITS

Stomach contents were examined from 62 age 0+ and 396 age I+ and older pygmy whitefish. The age 0+ fish were from South Bay and Brooks and Grosvenor Lakes, while the older fish were from Brooks, Grosvenor, and Hammersly Lakes, South Bay, North Arm, Iliuk Arm, and Brooks River. These fish were collected with seines, otter trawls, and gill nets.

DIET OF AGE I+ AND OLDER FISH

Insects and zooplankton were the two principal groups of food in the diet of age I+ and older pygmy whitefish in the Naknek system (table 8). The relative importance of these two foods varied greatly between lakes. Dipteran insects dominated

⁴ Two larger females, 102 and 115 mm. long were collected in North Arm with gill nets on Aug. 9, 1962. Both specimens were mutilated, however, and no scales were available for aging.

the South Bay and Iliuk Arm samples, while crustacean zooplankton dominated samples from Brooks Lake. Stomach samples from Brooks River fish contained predominantly insects, while samples from North Arm and Hammersly and Grosvenor Lakes fish contained about equal amounts of insects and zooplankton.

Larvae, pupae, and adult dipteran and plecopteran nymphs were the main insects eaten by Naknek system pygmy whitefish. Dipteran larvae and pupae (chiefly Chironomidae) accounted for 68, 50, 33, and 88 percent of the food volume from the four South Bay collections (table 8). Forty-seven percent of the volume of stomachs examined from Iliuk Arm consisted of dipteran adults. In all other samples, adult insects accounted for 5 percent or less of the volume. Plecopteran nymphs were the second most important insects eaten, accounting for 32 percent of the volume from a South Bay

sample and 40 percent from a Brooks River sample. Five additional orders of insects were occasionally eaten by pygmy whitefish, but these never accounted for more than 5 percent of the volume of any sample.

The principal crustacean foods eaten were the cladocerans *Daphnia*, *Bosmina*, and *Holopedium* and the copepods *Cyclops* and *Diaptomus* (table 8). The crustacean percentage of total volume varied from a trace (South Bay, August 24, 1962) to 100 percent (Brooks Lake, November 7, 1962). Ostracods and amphipods, which were the principal foods eaten by pygmy whitefish in Lake Superior (Eschmeyer and Bailey, 1955), were minor items in the diet of Naknek system fish, occurring in only 8 of 13 samples and never accounting for more than 6 percent of the sample volume.

TABLE 7.—Length frequencies of pygmy whitefish age I+ and older collected from various areas in the Naknek system, 1961-63
[M represents males; F, females; C, sexes combined]

Fork length in mm.	Brooks Lake								Grosvenor Lake				Hammersly Lake		
	Aug. 7, 1961		Sept. 14, 1961		June 29, 1962		July 10, 1962	Total	Aug. 5, 1962		Aug. 19, 1963	Total	Aug. 20, 1963		Total
	M	F	M	F	M	F	C		M	F	C		M	F	
26-28															
29-31															
32-34															
35-37															
38-40							1	1							
41-43							6	6							
44-46					9		23	32		1		1			
47-49	4	1	1		28	15	67	116		2	4	2			
50-52	9	9		2	68	64	254	406	2	4	1	7			
53-55	22	14	3	2	44	49	361	495	3	10	1	14			
56-58	15	14	6	4	5	3	276	323	1	5	7	13			
59-61	8	9	3	6	14	4	79	123	1	3	12	16			
62-64	1	7	3	5	14	11	111	152		2	10	12	1		1
65-67	1	5	1	4	8	13	114	146		3	3	6		1	1
68-70		3		3		8	102	116		3	6	9	1		1
71-73		3		2		6	97	108		2	10	12	2		4
74-76		1				1	54	56		10	9	19	2		2
77-79						1	18	19			4	4			
80-82							4	4		1	3	4		1	1
83-85											3	3		1	1
86-88											2	2			
89-91										1	2	3			
92-94											1	1			
95-97											1	1		1	1
98-100															
101-103															
104-106															
107-109															
110-112															
113-115															
116-118															
119-121															
122-124															
125-127															
128-130															
131-133															
134-136															
137-139															
140-142															
143-145															
146-148															
149-151															
152-154															

TABLE 7.—Length frequencies of pygmy whitefish age I+ and older collected from various areas in the Naknek system, 1961-63—Continued

Fork Length in mm.	North Arm			Iluk Arm					South Bay				
	July 21-Aug. 9, 1962		Total	Aug. 2, 1962		July 9, 1963	July 27, 1963	Total	July 22, 1962		Aug. 4, 1962		Total
	M	F		M	F	C	C		M	F	M	F	
26-28													
29-31													
32-34													
35-37													
38-40													
41-43													
44-46													
47-49													
50-52													
53-55					1	1		2		1			1
56-58						1		1					
59-61						4		4		1			1
62-64						5		5		1	2	7	10
65-67				1		4		5	1	4	12	13	30
68-70						5		5	6	3	23	56	88
71-73									13	14	95	107	229
74-76						2	3	3	11	12	174	244	441
77-79	3		3				1	2	14	8	193	229	444
80-82							2	2	2	6	124	145	277
83-85		3	3								52	45	97
86-88		4	4								10	9	19
89-91		7	7								2	1	3
92-94		5	5										
95-97		6	6			1		1				3	3
98-100		3	3		1			1			6	3	9
101-103		1	1		1		1	2	1	1	17	7	26
104-106									5		49	10	64
107-109						1	1	2	4	5	44	23	76
110-112									14	5	40	37	96
113-115		1	1				1	1	8	6	19	41	74
116-118									7	3	9	26	45
119-121						1		1	6	5	4	13	28
122-124					1			1	1	2	2	6	11
125-127										1	1	4	6
128-130						1	1	2	2		2	2	7
131-133						1	1	2	2	3		2	7
134-136										1		2	3
137-139										1		1	2
140-142										1		1	2
143-145													
146-148												2	2
149-151												2	2
152-154													

Other invertebrates found in the diet were pelecypods, nematodes, and arachnids (table 8). Only pelecypods, which accounted for from 5 to 13 percent in samples from North Arm and Brooks and Grosvenor Lakes, were of more than minor importance.

Periphyton (diatoms and other algae), which were present in one Brooks Lake sample and two Brooks River samples, never accounted for more than 4 percent by volume of any sample (table 8).

Fish eggs occurred in both of the Brooks River samples and in the November South Bay samples, amounting to 3, 14, and 38 percent of the volume of food (table 8). Although the eggs were partially digested in some stomachs and could not be identified, they all appeared to be salmon eggs. Large numbers of adult sockeye salmon spawn in Brooks River during the summer and early fall. Even after spawning is completed in the fall there is a frequent drift of dislodged eggs out of Brooks

River into South Bay. Kendall (1921) found salmonid eggs in stomachs of pygmy whitefish collected from Lake Aleknagik in August, and Eschmeyer and Bailey (1955) found whitefish eggs in stomachs of pygmy whitefish collected from Lake Superior in January. Eschmeyer and Bailey speculate that fish eggs, when available, may be an important item in the diet of the pygmy whitefish.

Sand grains accounted for 29 percent of the volume in the Grosvenor Lake sample and represented from 6 to 10 percent of the volume in four additional samples (table 8). Only two samples, both from Brooks Lake and containing principally zooplankton, were entirely devoid of sand grains. Occasionally fish were found with more than 100 sand grains in their stomachs. Eschmeyer and Bailey (1955) found sand grains in 9 percent of the Lake Superior fish examined.

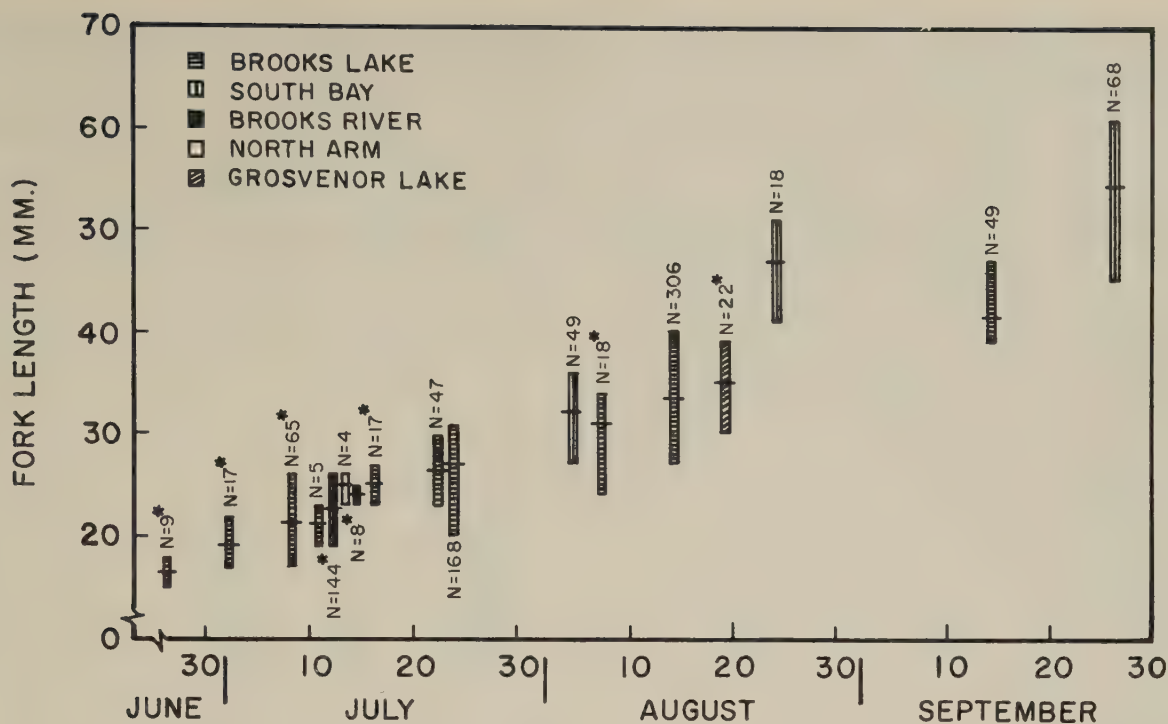


FIGURE 7.—Length frequencies of age 0+ pygmy whitefish collected in 1962 and 1963. Vertical bar represents length range; horizontal line represents mean length of each collection. Asterisk indicates collection was made in 1963.

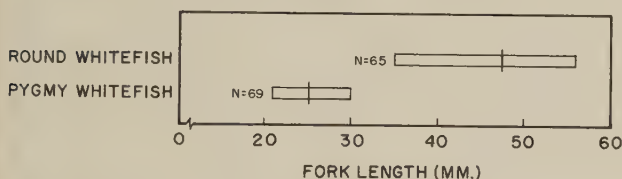


FIGURE 8.—Range and mean length of age 0+ round whitefish and pygmy whitefish caught in the same seine haul in Brooks Lake, August 10, 1962. Horizontal bar shows range; vertical bar indicates mean length of samples.

Plant debris such as small twigs, bits of wood, grass, seeds, and spruce needles occurred in nine samples and accounted for 14 percent of the volume in both samples from Brooks River (table 8). The relatively high occurrence of these items in Brooks River probably represents drift items.

The significance of fish scales in six samples (table 8) is not understood. All undigested scales that could be identified were from pygmy whitefish. No fish remains other than scales were found in any stomachs. Our observations suggest that pygmy whitefish might readily ingest any small bright object either in the current or from the stream or lake bottom.

Underwater observations of pygmy whitefish feeding in lower Brooks River showed that they frequently picked up mouthfuls of material off the bottom and passed fine silt, sand grains, and bits of debris posteriorly through their gill openings. They did not feed along the bottom in a suckerlike manner, but made short distinct jabs or darts, apparently at specific food items, such as insect larvae, when picking up mouthfuls of bottom material. Sand grains and other bits of debris are undoubtedly passed into the alimentary tract during such feeding behavior. Not all pygmy whitefish feeding activity in Brooks River was associated with the bottom. Frequently individual fish would rise off the bottom, as much as 35 to 50 cm. in water 1 m. deep and would pick specific items out of the passing current. With the diet of pygmy whitefish being primarily zooplankton and insects in various parts of the Naknek system and macrobenthic crustaceans in Lake Superior (Eschmeyer and Bailey, 1955), it is obvious that the species has a flexible diet and feeding behavior.

TABLE 8.—Percentage of total volume¹ of different food items in stomachs and (in parentheses) percent frequency occurrence² for 13 samples of age I+ and older pygmy whitefish taken with seines, gill nets, and otter trawls from various parts of the Naknek system

[T represents Trace]

Food item	South Bay				Brooks River		Iliuk Arm	North Arm	Grosvenor Lake	Ham-mersly Lake	Brooks Lake		
	Aug. 4, 1962, Seine	Aug. 24, 1962, Seine	Nov. 9, 1962, Seine	Apr. 16, 1963, Gill net	July 28, 1963, Seine	Aug. 24-25, 1963, Trawl	July 9, 1963, Seine	July 22-Aug. 9, 1962, Gill net	Aug. 19, 1963, Trawl	Aug. 17-20, 1962, Gill net	July 10, 1962, Trawl	Nov. 7, 1962, Trawl	July 22-26, 1962, Trawl
Insects:	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Dipteran:													
Larvae	49 (67)	9 (70)	33 (50)	87 (100)	9 (83)	14 (95)	7 (59)	34 (78)	28 (90)	28 (75)	T (25)		15 (57)
Pupae	19 (43)	41 (97)		1 (5)	9 (70)	24 (80)	16 (70)		5 (30)	34 (88)	1 (18)		T (5)
Adults	T (6)				1 (3)	5 (40)	47 (85)						4 (24)
Plecopteran:													
Nymphs	9 (13)	32 (73)			40 (73)	8 (43)	6 (44)						
Tricopteran:													
Larvae	2 (11)					T (10)			T (5)				
Other insects ³	T (2)					1 (13)	5 (30)						
Crustaceans:													
Cladocerans ⁴	4 (15)	T (10)	8 (40)	2 (21)	9 (37)	4 (40)	16 (81)	16 (67)	20 (85)	9 (38)	69 (100)	70 (100)	26 (76)
Copepods ⁵	1 (7)	T (3)	4 (10)	2 (21)	7 (23)	5 (43)	2 (30)	27 (89)	14 (65)	27 (62)	29 (95)	30 (94)	44 (100)
Ostracods	T (2)			1 (26)				3 (17)	T (5)	1 (38)	1 (34)		T (5)
Amphipods							T (4)						
Other invertebrates:													
Pelecypods ⁶								13 (28)	5 (10)				6 (5)
Nematodes		1 (10)		T (11)	T (10)	1 (32)	T (4)	5 (39)		T (25)			1 (38)
Arachnids		1 (17)				T (3)					T (2)		
Miscellaneous:													
Periphyton ⁷					T (10)	4 (35)							4 (10)
Fish eggs			38 (30)		3 (13)	14 (22)							
Sand grains	10 (67)	1 (27)	9 (80)	1 (26)	5 (37)	5 (82)	T (11)	1 (17)	29 (90)	1 (25)			T (10)
Plant debris ⁸	2 (17)	1 (20)	8 (30)	1 (21)	14 (60)	14 (70)	T (18)	T (6)					T (5)
Fish scales	3 (22)	15 (40)	T (10)		1 (30)	1 (27)	T (22)						
Number of stomachs examined	60	30	20	20	30	63	27	20	21	9	44	31	21
Percent empty stomachs	10	0	50	5	0	5	0	10	5	11	0	0	0
Length range	68-130	72-113	100-134	80-111	97-136	81-144	56-130	76-100	52-97	68-80	53-80	55-77	55-77
Mean volume of contents ² (in ml.) per stomach	0.11	0.23	0.13	0.09	0.27	0.46	0.39	0.10	0.18	0.12	0.18	0.17	0.06

¹ Based on aggregate contents of all stomachs in each sample.

² Based only on stomachs containing food.

³ Tricopteran adults, coleopteran adults and larvae, hemipteran, hymenopteran, and collembolan adults.

⁴ *Daphnia longiremis*, *D. rosea*, *Bosmina coregoni*, *Holopedium gibberum*.

⁵ *Cyclops strenuus* and *Diaptomus gracilis*.

⁶ *Pisidium*.

⁷ Diatoms and filamentous algae.

⁸ Small sticks, bits of wood, seeds, and leaves.

DIET OF AGE 0+ FISH

Crustacean zooplankton was the major food in two samples of age 0+ fish—one from South Bay, July 11, 1963, and one from Brooks Lake, August 14, 1962. Insects and zooplankton were about equal in volume in the September 26, 1962, South Bay and August 19, 1963, Grosvenor Lake samples (fig. 9). It appears that in those areas where insects are heavily utilized by older pygmy whitefish, the diet shift of fish from zooplankton to insects occurs late during the first summer of life. Eschmeyer and Bailey (1955) found copepods to

be the dominant food of age 0+ pygmy whitefish from Lake Superior in September.

DIET VARIATIONS IN DIET

The sample of age I+ and older fish from Brooks River on August 24-25, 1963 (table 8), was collected from the same riffle area at four adjacent 6-hour intervals to determine diel differences in quantity and quality of foods eaten. No significant difference in the composition of diet items was found throughout the 24-hour period; however, the average volume of food material per

stomach was three times as great at midday as at midnight (fig. 10). The most intense feeding period during this 24-hour period apparently was during daylight hours and not during darkness.

COMPARISONS OF GROWTH AND DIET

By comparing the dramatically different growth rates and sizes that pygmy whitefish at-

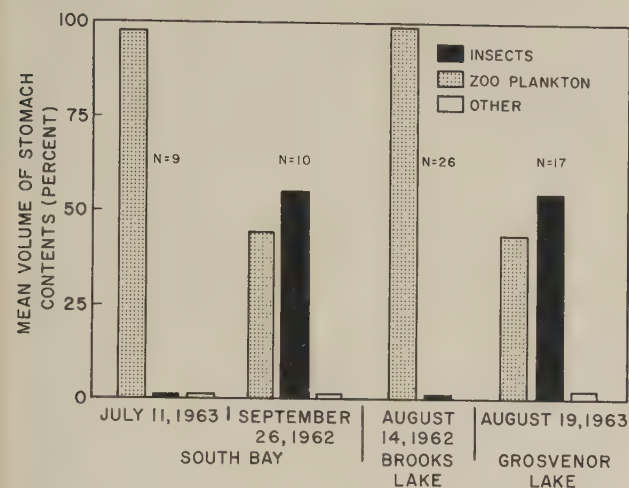


FIGURE 9.—Percent of total volume of stomach contents of age 0+ pygmy whitefish by major food categories.

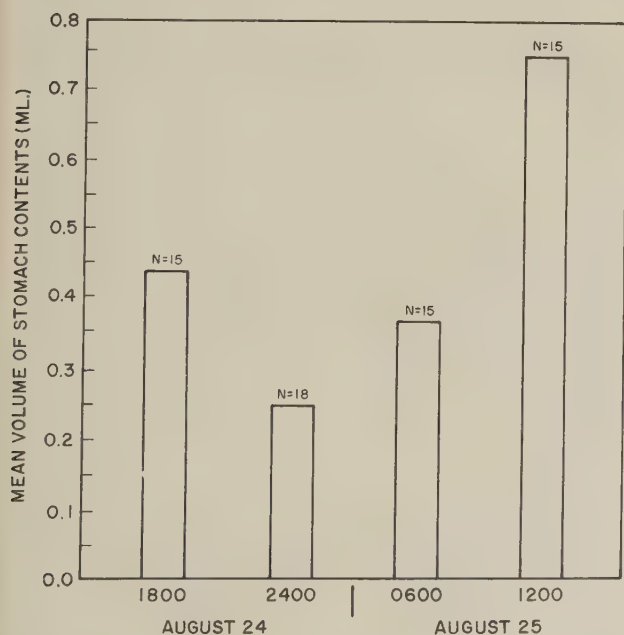


FIGURE 10.—Variation by time of day in mean volumes of stomach contents of 63 pygmy whitefish caught at 6-hour intervals from the same area in Brooks River, August 24 and 25, 1963.

tain in the Naknek system (figs. 2 and 6) with the differences in diet, a strong positive correlation between size of fish and utilization of insects becomes apparent. An analysis was made by first grouping all contents from each sample into three categories (insects, zooplankton, and other), then grouping the samples according to the relative importance of insects and zooplankton. Three rather distinct groups of samples resulted: one with heavy, one with moderate, and one with almost no insect utilization. These grouped samples compared with the largest known pygmy whitefish from the same grouped areas (fig. 11) illustrate the correlation between insect utilization and size. Maximum size is not the only index, because the general ranges of length frequencies from different parts of the system (table 7) fall into the same groupings. If this correlation is biologically valid, it raises a question as to why Brooks Lake pygmy whitefish do not eat insects. Merrell (1964) has shown that other Brooks Lake fishes utilize insects, which indicates their general availability. No comparative data are available, however, on differences in insect populations in the Naknek system.

Preference for, access to, or utilization of specific foods may not directly account for differences in growth rates of pygmy whitefish populations in Brooks Lake and South Bay-Iliuk Arm. Basic differences in ecological characteristics of the areas such as morphometry, limnology, productivity,

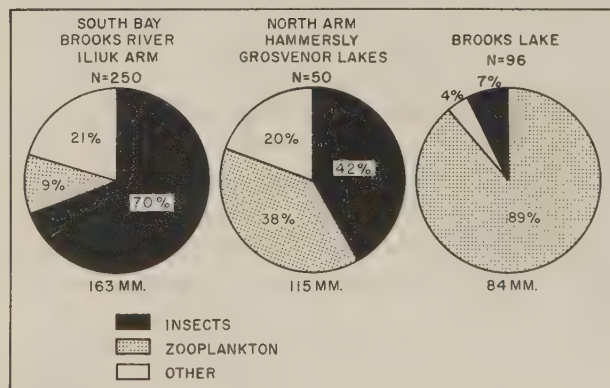


FIGURE 11.—Relative importance of insects, zooplankton, and other foods in diet of pygmy whitefish from three areas of Naknek system. Data based on percent of sample volumes shown in table 8. Number beneath each figure represents largest pygmy whitefish collected from the grouped area.

species combinations of fishes, and food organisms are interwoven in a complex of relations that result in distinctly different environments. Differences in growth rates, longevity, and food habits of pygmy whitefish in the Naknek system probably reflect adaptive responses to these overall environmental differences and not simply the availability or use of certain food items.

The differences we found in *Prosopium coulteri* populations in Brooks Lake and South Bay-Iliuk Arm parallel the differences in *Coregonus peled* (Gmelin) populations in the Swedish lakes Vjomsjon and Uddjaur-Storavan (Lindstrom and Nilsson, 1962). In Sweden, *C. peled* was a slow-growing plankton feeder in Lake Vjomsjon and a fast-growing insect feeder in Lakes Uddjaur-Storavan. As previously discussed, *P. coulteri* is a slow-growing plankton feeder in Brooks Lake and a fast-growing insect feeder in South Bay-Iliuk Arm. Lake Vjomsjon had fewer associated whitefish species, proportionately less littoral area, and probably lower productivity than Lakes Uddjaur-Storavan. In the Naknek system, Brooks Lake has fewer associated whitefish species, less littoral area, and lower productivity than South Bay-Iliuk Arm. The observed plasticity of the genus *Prosopium* in response to environmental differences in the Naknek system is similar to that widely recognized in coregonid and leucichthid whitefishes (Walters, 1955; Svardson, 1957; and others). The variability in meristics and morphology found in pygmy whitefish by McCart (1963) also emphasizes this plasticity in *Prosopium*.

REPRODUCTION

Data on pygmy whitefish reproduction were collected from various areas as follows: sex ratio and age and size at maturity—South Bay and Brooks Lake; fecundity—South Bay, Brooks Lake, and North Arm; and seasonal maturation and spawning behavior—South Bay and Brooks River.

SEX RATIOS

Only a few large samples from Brooks Lake and South Bay were processed for sex ratios, but they revealed nearly equal ratios (table 9). The largest specimens were almost always females (table 7), a phenomenon undoubtedly due to the greater longevity and the faster growth rate of females.

These larger females, however, constituted a numerically minor segment of the population. Eschmeyer and Bailey (1955) and McCart (1963) also found females to be the oldest and largest fish in their collections.

TABLE 9.—Sex ratios of pygmy whitefish, Brooks Lake and South Bay, collected during the summers 1961–62

Location and date	Number of fish	Sex ratio females to males
Brooks Lake:		
Aug. 7, 1961	127	1:0.92
June 29, 1962	365	1:1.08
South Bay:		
July 23, 1962	182	1:1.13
Aug. 24, 1962	1,907	1:0.82

AGE AND SIZE AT MATURITY

The degree of maturity in age groups I and II varied between lake populations and between sexes within a single population (table 10). In Brooks Lake 10 percent of the females and 36 percent of the males reached sexual maturity during their second growing season (age I+). In South Bay no females and only 2 percent of the males matured as age I+ fish. In both lakes more than 95 percent of the age II+ fish and all of the older fish were mature.

TABLE 10.—Age at maturity of pygmy whitefish collected during the summer and fall from Brooks Lake and South Bay, 1961–62

Age	Brooks Lake				South Bay			
	Males		Females		Males		Females	
	Fish in sample	Ma-ture	Fish in sample	Ma-ture	Fish in sample	Ma-ture	Fish in sample	Ma-ture
	Num-ber	Per-cent	Num-ber	Per-cent	Num-ber	Per-cent	Num-ber	Per-cent
I+-----	67	36	58	10	160	2	175	0
II+-----	28	96	96	97	214	99	181	97
III+-----	2	100	11	100	14	100	16	100
IV+-----					4	100	12	100
V+-----							2	100

In Brooks Lake and South Bay, only a slight tendency exists for males to mature at a smaller size than females. In contrast, Eschmeyer and Bailey (1955) found 100 percent of the males mature at sizes smaller than the smallest mature females. Because of the great differences in growth rates in the Naknek system, there is no overlap in the size at maturity between Brooks Lake and South Bay pygmy whitefish (table 11).

TABLE 11.—Size at maturity of pygmy whitefish collected during the summer and fall from Brooks Lake and South Bay, 1961–62

Length groups	Brooks Lake				South Bay			
	Males		Females		Males		Females	
	Fish in sample		Fish in sample		Fish in sample		Fish in sample	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Mm.								
44–46	10	0						
47–49	35	0	16	0				
50–52	81	0	72	0				
53–55	73	8	71	0			1	0
56–58	28	29	29	3				
59–61	25	76	19	21			1	0
62–64	18	94	24	71	2	0	8	0
65–67	13	100	26	96	13	0	17	0
68–70	3	100	22	100	29	0	59	0
71–73	3	100	36	100	105	0	121	0
74–76			20	100	185	0	256	0
77–79			4	100	207	0	237	0
80–82			2	100	126	2	151	0
83–85					42	5	45	2
86–88					10	20	9	11
89–91					1	0		
92–94								
95–97							3	67
98–100					6	100	2	100
101–103					18	94	8	100
104–106					54	100	10	100
107–109					48	98	28	90
110–112					54	100	42	98
113–115					27	100	47	98
116–118					15	100	29	100
119–121					10	100	18	100
122–124					3	100	8	100
125–127					1	100	5	100
128–130					4	100	3	100
131–133					2	100	6	100
134–136					2	100	5	100
137–139							4	100
140–142							3	100
143–145								
146–148							5	100
161–163							1	100

FECUNDITY

The total number of maturing eggs in pygmy whitefish ovaries were counted for 59 fish from South Bay, 19 from Brooks Lake, and 7 from North Arm. The number of eggs ranged from 103 to 1,153 per female. Body length-fecundity equations computed for each sample showed some difference between areas. However, a single equation was determined (fig. 12) by grouping all 85 females, because there was no overlap in the size range of females between samples.

The salient features of these fecundity data are (1) that a broad range of fecundities exists in different parts of the system and (2) that pygmy whitefish from the Naknek system are considerably more fecund than the same size fish from Lake Superior. We transformed the total length-fecundity relation given by Eschmeyer and Bailey (1955) into a fork length-fecundity relation for comparison with our data. A 120-mm. female

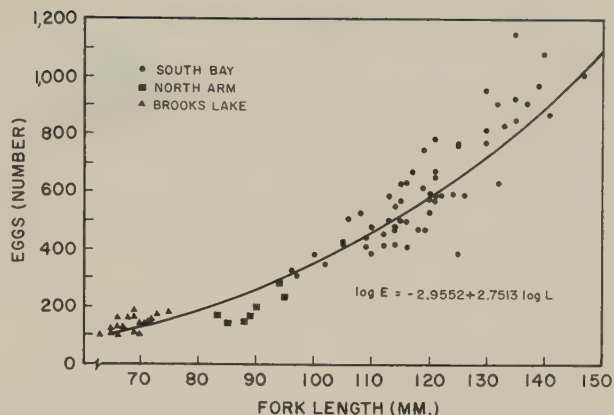


FIGURE 12.—Length-fecundity relation of pygmy whitefish from three areas of Naknek system. Equation derived by combining data from the three areas.

from Lake Superior (130 mm. total length) averaged about 440 eggs, while the same size female from the Naknek system averaged about 580 eggs. These differences in fecundity could be adaptive responses of the various populations to different environmental conditions that produce higher or lower survival opportunities for the species (Svardson, 1949; Nikolsky, 1963).

SPAWNING SEASON AND BEHAVIOR

Egg size in maturing females from South Bay in 1962 increased markedly between late summer and the fall spawning period. Egg diameters that averaged 1.1 mm. in early August increased to 2.4 mm. in ripe females in early November, while ovary weight increased from 3.5 to 16.5 percent of the total body weight (fig. 13). Egg size and ovary weight relative to body weight in near ripe fish from Lake Superior (Eschmeyer and Bailey, 1955) were 2.0 mm. and 15 percent.

Spawning of pygmy whitefish in Brooks Lake and South Bay in 1962 and 1963 apparently occurred between mid-November and mid-December. Mature, ripe males and females from South Bay were collected near the mouth of Brooks River on November 7 and 9, 1962. The water temperature in South Bay on November 9, 1962, was 3.9° C. Both eggs and sperm could easily be extruded by exerting slight pressure on the abdomen, and females as well as males were tuberculate over much of the body. The ventral fins of both sexes were orange. Pygmy whitefish from Brooks Lake on November 7, 1962, were not quite

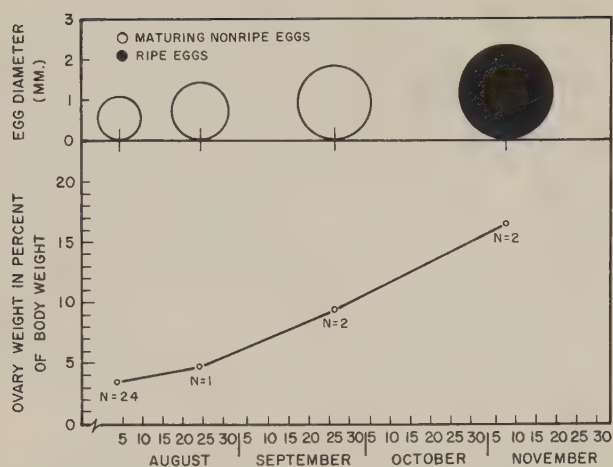


FIGURE 13.—Seasonal maturation of pygmy whitefish collected from South Bay, 1962. Average egg diameter based on minimum of 10 eggs per female. N equals number of females examined.

as ripe as those from South Bay. Although mature fish taken in South Bay on October 29 and November 5, 1963, were not quite ripe, three specimens taken from Brooks River on the night of November 6 apparently were, because sex products could be readily extruded from them.

The spawning period in the Naknek system agrees with most other spawning information on pygmy whitefish. The time of spawning in Lake Superior (Eschmeyer and Bailey, 1955), Glacier National Park, Mont. (Schultz, 1941), and four British Columbia lakes (McCart, 1963) was believed to be in November or December. The November–December spawning in the Naknek system compares closely with the supposed time of spawning in Lake Superior and Glacier National Park, Mont. (Eschmeyer and Bailey, 1955; and Schultz, 1941). Weisel and Dillon (1954) collected sexually mature and spent pygmy whitefish from Bull Lake between December 26 and January 12. Kendall (1917 and 1921) reported on six pygmy whitefish collected from the Chignik River system, Alaska, about November 1, 1912. These fish (Kendall, 1921) were “mature individuals ready to spawn,” which agrees with the other known spawning times of this species.

Exceptions to the late fall and winter spawning of pygmy whitefish have been noted. Kendall (1921) reported that some pygmy whitefish collected on July 20, 1909, and August 2, 1912, from the outlet of Lake Aleknagik were in breeding

condition. Apparently the collector of one of these samples reported that pygmy whitefish were passing out of Lake Aleknagik in large numbers, and Kendall interpreted this as a spawning run. We question the validity of this interpretation and doubt that a spawning migration was occurring as early as July 20 or August 2, although individual specimens might have seemed ready to spawn. McCart (1963) found a physiologically atypical female in Cluculz Lake, British Columbia, on July 15, 1962, which appeared to be ripe. We examined pygmy whitefish collected on July 13, 1963, from Wood River just below the outlet of Lake Aleknagik by Dr. R. L. Burgner of the Fisheries Research Institute, University of Washington, and found the condition of the gonads to be 3 or 4 months from full maturity. Two of the Wood River females had average egg diameters of 1.0 mm., and the ovaries made up only 2.7 percent of the body weight (fig. 13). Burgner (personal communication) reports that large numbers of pygmy whitefish can be seen throughout much of the summer in Wood River below Lake Aleknagik. These observations and Kendall's (1921) comments on fish passing out of the lake could represent the seasonal feeding movements of a lake population similar to that observed during the summer in South Bay and lower Brooks River. Pygmy whitefish may spawn below Lake Aleknagik, but probably later than Kendall believed.

Although specific details of spawning behavior were not observed, we determined that pygmy whitefish (in Brooks River at least) spawn only at night, as do mountain whitefish in Montana (Brown, 1952). Routine underwater surveys in early November in 1962 and 1963 revealed no pygmy whitefish in Brooks River during daylight hours, although large numbers of ripe or nearly ripe fish were known to be in South Bay off the river mouth. On a dive just after dusk on November 5, 1963, divers using underwater hand lamps observed that a few large pygmy whitefish had moved into lower Brooks River from South Bay. Between 20 and 25 pygmy whitefish were observed in the same area the following night about 3 hours after darkness. These fish probably represented the beginning of the spawning run in 1963.

South Bay fish probably remain in the lake in the vicinity of Brooks River until they reach full maturity, when they move into the river at night

to spawn. Periodic observations along the stream-bank at night with a lantern in late November and early December in 1963 continued to reveal the presence of pygmy whitefish in the stream. Unseasonably cold temperature, however, caused ice conditions that precluded intensive observations. About 100 fish were seen just at the mouth of Brooks River during a night dive on December 16, 1963. Most of these fish were individually scattered over the stream bottom, although one congregation of 8 to 10 fish may have represented a spawning group. These particular fish darted wildly about upon encountering the underwater spotlight. The water temperature in Brooks River on December 16 was 0.3° C. All adult pygmy whitefish taken in gill nets under ice in South Bay near the river mouth on December 12 and 18 were spent.

DISCUSSION

In the Naknek River system pygmy whitefish apparently reach their greatest density in Brooks Lake where they may be the most abundant species in the lake. These conclusions are based on the combined numbers of each species caught in all sampling gears from 1961 to 1963. In Brooks Lake, South Bay, and Iliuk Arm, pygmy whitefish are commonly associated with juvenile sockeye salmon. This relation merits consideration because of the commercial value of the Naknek River system sockeye salmon.

Although the association of two species pre-determines some sort of interspecific relation, in fishes it is usually difficult to determine the exact nature of this relation. Larkin (1956), who considered competition in a concise limited sense, points out that competition itself is difficult to separate from other complex interrelations between fish species. Rogers (1961), after carefully considering the diets of young-of-the-year sockeye salmon and three age groups of threespine sticklebacks collected from similar ecological areas of Wood River Lakes, could only conclude that "potential food competition exists." Greenbank and Nelson (1959), in studying the threespine stickleback in Karluk Lake, conclude that "Quantitative information is insufficient to assess accurately the benefit or harm to salmon production caused by the stickleback population." Johnannes and Larkin (1961) could demonstrate severe competition be-

tween redbside shiners (*Richardsonius balteatus*) and rainbow trout for amphipods in Paul Lake, British Columbia, only because of long-term data that included preshiner amphipod densities along with feeding habits and growth rates of the trout.

In the present study it is impossible on the basis of existing data to demonstrate direct interspecific competition in any form between pygmy whitefish and juvenile sockeye salmon or other whitefishes. It is possible, however, that the combined effects of interspecific and intraspecific relations of these species may influence the growth and general well-being of each in various parts of the Naknek system. Although McCart (1963) could not demonstrate direct competition between pygmy whitefish and other whitefishes, he found indications of interactive segregation between whitefishes which resulted in differences in depth distribution and growth rates. He also noted that the large MacLure and McLeese Lake pygmy whitefish were the only ones in British Columbia that did not coexist with another species of the genus *Prosopium*. In the present study the largest pygmy whitefish were found in South Bay and Iliuk Arm where three other whitefishes occur (round and humpback whitefish and least cisco), while the smallest pygmy whitefish were found in Brooks Lake where round whitefish is the only other whitefish. Although growth rates of pygmy whitefish in the Naknek system are correlated with different diets, McCart (1963) found no differences in diets of this fish in four lakes where growth was quite different.

Both pygmy whitefish and juvenile sockeye salmon feed heavily on zooplankton in Brooks Lake, although Merrell (1964) points out that during late spring and early summer, insects may be the most important item in the diet of Brooks Lake sockeye salmon (age I+ and older). Even though differences in the production of sockeye salmon smolts in Brooks Lake have varied from 60,000 to 360,000 during recent years, there has been little difference in the mean size of age I+ smolts. This suggests that densities of young salmon, together with other environmental influences such as potentially competitive dense populations of pygmy whitefish, have not altered the basic growth rate of sockeye salmon in Brooks Lake.

Interspecific association of juvenile sockeye salmon and pygmy whitefish in South Bay and Iliuk

Arm is complicated by several factors. First, a greater number of other associated species occur in these areas than in Brooks Lake. Second, in addition to serving as primary rearing areas for salmon produced in adjacent spawning areas such as Brooks River and Margot Creek (a tributary of Iliuk Arm), both South Bay and Iliuk Arm, of necessity, serve as migration lanes for salmon produced in upsystem areas. This point is further complicated by interlake movement whereby some juvenile sockeye salmon begin their nursery lake existence in upstream lakes (i.e. Coville and Brooks), then migrate into downstream nursery areas (i.e. Iliuk Arm and South Bay) to complete their first year of life.⁵ Thus, the juvenile sockeye salmon populations in South Bay and Iliuk Arm are frequently undergoing dramatic changes in density apart from normal fluctuations in the local population. Although pygmy whitefish feed primarily on insects in South Bay and Iliuk Arm, the diet of young sockeye salmon in these areas is not known. It may be that no possible food competition exists between these species in South Bay and Iliuk Arm.

The reasons for the marked differences in the biology of pygmy whitefish populations in Brooks Lake and South Bay are poorly understood. Pygmy whitefish in Brooks Lake grow slower, mature earlier, and live shorter lives than those in South Bay or Iliuk Arm. Consequently, spawning females are younger, significantly smaller, and less fecund in Brooks Lake. Yet, the species is extremely successful in Brooks Lake, as evidenced by abundance. Factors contributing to this success undoubtedly deal with lower mortalities from fertilized egg to maturity. Because of early maturity, short life span, and small size, pygmy whitefish in Brooks Lake fit the concept of a "dwarfed or small form" discussed by Svardson (1957), Alm (1959), and Fenderson (1964). As pointed out by Alm, a "dwarfed form" with short life and early maturity is distinct from a slow-growing "normal form" which has greater longevity and matures at an older age but still at a small size. Dwarfism may provide a species with advantages

in survival and competition (Lindstrom and Nilsson, 1962; McCart, 1963; and Fenderson, 1964).

On the basis of recent data from Lake Aleknagik and Chignik Lake, Peter J. McCart (personal communication) believes that two distinct sub-populations of pygmy whitefish may occur sympatrically in these lakes. One form, which is generally larger, is a river-oriented insect feeder with low gill raker counts and is apparently confined to shallow water. The other form is a lake-oriented plankton feeder with high gill raker counts and inhabits deep water. These criteria, in part, apply to some of the differences found in populations in the Naknek system. This is particularly true with the insect feeders in South Bay where the population is strongly oriented to Brooks River and the relatively shallow waters of South Bay. In other parts of the system, however, differences in ecological distribution represent exceptions to this general scheme. In Iliuk Arm, large fast-growing insect feeders occur from shallow beaches to maximum depths of 168 m., whereas in Brooks Lake, slow-growing insect feeders occur from the shallow to the deepest depths. Although we have not studied meristic variation of populations of pygmy whitefish in the Naknek system in detail, the insect feeders in South Bay and Brooks River have lower gill raker counts than the plankton feeders in Brooks Lake. Eschmeyer and Bailey (1954, p. 174) point out that gill rakers from pygmy whitefish in rivers, or lakes dominated by rivers, tend to be fewer in number and shorter in length than those from lacustrine environments. Whether differences found in populations of pygmy whitefish in the Naknek system represent genetically distinct subpopulations or the adaptive responses of the species in utilizing the many environments present in the system cannot be determined without additional study.

Differences in diet in various parts of the system have been discussed and correlated with growth rates. Actually, growth rates are correlated not only with the degree of insect utilization but also with the rate of phytoplankton productivity in various areas. Primary productivity is relatively high in South Bay and Iliuk Arm, low in Brooks Lake, and intermediate in North Arm and Grosvenor Lake.⁶ A notable exception to correlating growth rates of pygmy whitefish with primary

⁵ Summary report of studies on the optimum escapement of sockeye salmon in southwestern Alaska, 1961-62. Prepared by the Bureau of Commercial Fisheries Biological Laboratory, Auke Bay, Alaska, and Fisheries Research Institute, University of Washington, Seattle. (Manuscript on file at the BCF Laboratory.)

⁶ See footnote 2 on p. 557.

productivity is that Coville Lake, which has the shallowest mean depth, the highest water temperatures, and the highest primary productivity in the system, apparently has only a small population of intermediate size pygmy whitefish; however, Coville Lake may have denser populations of other species (i.e. pond smelt, humpback whitefish, and juvenile sockeye salmon) than other parts of the system.

Until comparative data are available on the relative abundance of various food groups and the diets of associated fishes in different areas, it is impossible to determine the role of food availability or preference for specific foods in evaluating differences in the biology of pygmy whitefish in the Naknek system. Rather than simple differences in diet, growth, or ecological distribution, we feel the dramatic differences found in pygmy whitefish populations in the Naknek system probably reflect widely varying adaptive responses of a highly plastic species to the complex of environmental differences found throughout the system.

SUMMARY

The pygmy whitefish has the greatest discontinuous distribution of any fresh-water fish in North America, occurring in the Atlantic, Pacific, and Arctic Ocean drainages. It is widely distributed and locally abundant in lakes of the Naknek River System in southwest Alaska.

More than 10,000 pygmy whitefish were collected from the Naknek system with seines, otter trawls, tow nets, and gill nets from 1961 to 1963. This species seems to have a prominent role in the dynamics of some Naknek system fish populations.

In the Naknek system, pygmy whitefish occur in all benthic areas from shallow littoral depths to the deepest areas available. Seasonally, in certain age groups and in certain areas, they occur in limnetic waters of lakes and in streams.

Nineteen species, including the closely related round whitefish, occurred in catches with pygmy whitefish in various parts of the Naknek system.

Polynomial equations were used to express the curvilinear relation between body length and anterior scale radius. Body length at scale formation is about 25 mm.

The oldest and largest fish from the two areas studied most intensively was an age V 163-mm. female from South Bay and an age III 84-mm.

female from Brooks Lake. Length frequency distributions from other areas were intermediate between these extremes. Calculated and observed growth indicated that growth was much greater in South Bay than in Brooks Lake. Both sexes in Brooks Lake showed a tendency to mature at an earlier age than in South Bay.

Dipteran insects were the principal foods eaten by pygmy whitefish in South Bay. Crustacean plankton dominated their diet in Brooks Lake. In other areas insect and zooplankton foods were about equal in importance. In areas where insects were important in the diet of older fish, the shift from zooplankton to insect foods in age 0+ fish began during the first summer of life. A positive correlation between growth and insect utilization was found.

The fork length-fecundity relation of Naknek system pygmy whitefish is expressed by the equation

$$\text{Log } E = -2.9552 + 2.7513 \log L.$$

where E equals number of eggs per female and L equals fork length of the fish. Fecundity in Naknek system fish exceeds that in Lake Superior fish.

Spawning occurs in November and December. South Bay fish move into Brooks River for spawning only at night. Eggs in ripe fish from South Bay averaged 2.4 mm. in diameter, and the ovaries were 16.5 percent of the body weight.

Potential interspecific competition exists between pygmy whitefish and juvenile sockeye salmon, particularly in Brooks Lake where foods are similar and the whitefish are numerous.

Slow growth, low fecundity, and short life characterize Brooks Lake pygmy whitefish. These factors must be compensated for by lower mortality from fertilized egg to maturity than in the South Bay population, which is characterized by fast growth, higher fecundity, and longer life.

The wide range in growth rate, fecundity, longevity, and diet of populations of pygmy whitefish in the Naknek system is probably due to the adaptive responses of a highly plastic species to the variety of environmental characteristics, such as water quality and clarity, drainage geology, phytoplankton productivity, lake morphometry, fish species, and food organism associations found in different parts of the system.

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A REVIEW OF WESTERN ATLANTIC CAT SHARKS, SCYLORHINIDAE, WITH DESCRIPTIONS OF A NEW GENUS AND FIVE NEW SPECIES

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ABSTRACT

A new genus *Schroederichthys* is described, together with its type species *Schroederichthys maculatus* from the western Caribbean and a second species *Schroederichthys tenuis* from the Atlantic off Brazil. *Scyliorhinus meadi* from the east coast of Florida,

Scyliorhinus hesperius from the western Caribbean, and *Galeus cadenati* from the vicinity of Panama are also described. All 15 of the known western Atlantic species are illustrated, and species characters thought to be of value for revisionary studies are noted.

The purpose of this paper is to review the western Atlantic cat sharks with especial attention to description of those characteristics of genera and species that are of interest for a revision of the cat sharks of the world; and also to describe new material collected by exploratory fishing vessels of the Bureau of Commercial Fisheries in the western Atlantic, including representatives of a new genus and five new species.

For a revision of the family, more material should be examined than is now available in American museum collections. The distinctions between the genera *Scyliorhinus* and *Halaelurus*, for example, appear to be somewhat superficial, but a revision of generic arrangement is impractical without a survey of all known species and the use of a greater number of diagnostic characters than can be gleaned from the terse and noninformative descriptions of many of the nominal species. A family revision which is in progress will provide a better opportunity for treatment of genera.

SOURCES OF MATERIAL

Collections of cat sharks made by the Bureau of Commercial Fisheries exploratory fishing vessels,

Oregon, *Silver Bay*, and *Combat*, are the principal source of material for this report. Studies of these collections were supplemented by examination of the relatively small numbers of cat sharks in the U.S. National Museum, the Museum of Comparative Zoology at Harvard College, and the Natural History Museum of Stanford University. An important series of *Apristurus* in the Museum of Comparative Zoology collected by the *Cap'n Bill II*, a fishing vessel chartered by the Woods Hole Oceanographic Institution, was examined. For purposes of comparison, an excellent series of the Pacific species, *Apristurus brunneus* (Gilbert) was assembled from specimens collected from the research vessels of the University of Washington College of Fisheries and by the exploratory vessel *John N. Cobb* of the Bureau of Commercial Fisheries. Similarly a young example of *Cephaloscyllium uter* (Jordan and Gilbert) and also a series of the Pacific cat shark *Parmaturus xanthurus* (Gilbert) were obtained for comparison with Atlantic scyliorhinids from collections made by the research vessel *N. B. Scofield* of the California Department of Fish and Game. The type of *Scyllium laurussonii* Saemundsson was loaned by the Natural History Museum, Reykjavik, Iceland, for examination.

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No specimens from the coast of Argentina were seen. *Halaehurus bivius* (Smith) has been recorded from Argentina by Berg (1895), Lahille (1921, 1928), and Norman (1937). *Halaehurus chilensis* (Guichenot) mentioned by Lahille (1928) as a synonym of *Halaehurus bivius* (Smith) probably is a valid species and two species referable to *Halaehurus* occur in Argentine waters according to information received from Professor Elvira M. Siccardi (personal communication). Professor Siccardi also found a population of *Scyliorhinus* on the coast of Argentina, either *S. boa* (Goode and Bean) or an undescribed species very similar to *S. boa*. Species found on the coast of Argentina are given very brief treatment here, based chiefly on photographs, measurements, and records of specimens that Professor Siccardi has kindly allowed me to see. Illustrations in this paper of *Halaehurus* are of specimens from Chile in the collection of the U.S. National Museum.

Ideal study series, that is, series including adults of both sexes, young in various states of growth, and specimens collected from a number of localities sufficient to outline the probable limits of geographical and vertical distribution, are not available for any of the 15 species treated here. For example: available specimens of *Scyliorhinus retifer* (Garman) satisfy ideal requirements except that no adult females with eggs have been examined; the series of *Apristurus riveri* Bigelow and Schroeder includes two adult males and three adult females, one with a partly extruded egg case, and a few young examples, material sufficient to show sexual dimorphism in the teeth of the adults and to show the oviparous habit, but the series lacks immature males.

Family SCYLIORHINIDAE

The definition of the family given by Bigelow and Schroeder (1948, pp. 195-196) is followed provisionally. Separation of the cat sharks from members of the family Orectolobidae on the basis of external form is comparatively simple when dealing with American material. No Atlantic American cat shark has barbels or has the nostrils connected with the mouth by a groove, while orectolobids in general have these characteristics. One Indian Ocean genus, *Conoporoderma*, referred to Scyliorhinidae by Bigelow and Schroeder, has barbels and another, *Haploblepharus*, does have

the nostrils connected with the mouth by a groove. Otherwise the use of these characters to separate the Scyliorhinidae from the Orectolobidae is the most practical one. Of the characters given by Bigelow and Schroeder for separation of the two families, Orectolobidae and Scyliorhinidae (1948, pp. 178 and 195), the only characterization of the Scyliorhinidae always applicable is that the scyliorhinids have three rostral cartilages, united at their tips; whereas orectolobids have none, one, or three rostral cartilages which are small and, if present, are not united at their tips. I have verified this only in a few western Atlantic species. Even tooth characters do not hold unless exceptions are noted. Adult males of *Apristurus riveri* Bigelow and Schroeder, instead of having small teeth with several cusps as in all other known scyliorhinids including female *A. riveri*, have single cusped teeth in about 20 median rows.

Grace White (1936), commenting on forms generally known as cat sharks, states that variation in the catuloids (cat sharks and allied groups) is so extreme as to make the distinction even among genera difficult. Certainly it is difficult to find family characteristics to which there are no exceptions and which set off scyliorhinids sharply from obviously related families. Although there has been reasonably general agreement on the kinds of sharks constituting the group known by the common name cat shark, precise morphological definitions of the family or families constituting the cat sharks and their allies have been various and apparently not entirely satisfactory even to those proposing the definitions. The cat sharks are, with few exceptions, small demersal forms of moderately deep water, and, again with exceptions, are not well known and are poorly represented in study collections. It is not unlikely that the group contains representatives of several evolutionary lines and that at the family level most of the classifications that have been proposed embrace horizontal groupings.

Müller and Henle (1841) placed all the sharks known by them to be egg layers in the family Scyllia, including both the scyliorhinids and the orectolobids without making a distinction between sharks in which egg cases are resorbed after formation or are retained in the oviducts until hatching (ovoviviparous species) and forms that discharge eggs in leathery cases at an early stage in

development (oviparous species). It has long been known that orectolobid species are either oviparous or ovoviviparous, but according to Bigelow and Schroeder (1948, p. 196), the scyliorhinids so far as known are oviparous. Poll (1951) and Cadenat (1959) subsequently reported the ovoviviparous condition in one species of *Galeus*. Probably more data will show that additional scyliorhinid species are ovoviviparous.

Regan (1908) separated the scyliorhinids and orectolobids as families and included *Pseudotriakis* in the Scyliorhinidae. He recognized only two other genera in the family and included especially divergent species within the genus *Scyliorhinus*. White (1937), with the intention of providing a vertical classification that would better reflect phylogenetic lines, proposed two new families, Aetelomycteridae and Halaeluridae, and retained the family Catulidae (= Scyliorhinidae). All genera of these three families of White excepting *Pristiurus* (= *Galeus*) were included in Regan's genus *Scyliorhinus*.

Bertin (1939) in a review of the classification of the cartilaginous fishes placed the cat sharks together with the orectolobids in the family Scyliorhinidae, but placed *Pseudotriakis* and *Pentanchus* in monotypic families. *Pseudotriakis* has a very long and low first dorsal fin with its base entirely in advance of the pelvic fins, and this is the primary morphological feature separating it from the scyliorhinids which have short-based dorsal fins (or single dorsal fin) located posteriorly, over or behind the pelvis. *Pseudotriakis* is represented by two large species, one, *Pseudotriakis microdon* Brito Capello, reported from the western Atlantic. Both species are larger than any known cat sharks. Although *Pseudotriakis* is not treated here as a member of the family Scyliorhinidae, its relegation to another family may not be warranted. The distinctive arrangement of tooth rows as diagonal bands characteristic of *Pseudotriakis* also occurs to a lesser degree in *Aetelomycterus* and has some similarities to the tooth arrangement in *Apristurus*. Additional similarities are found between *Pseudotriakis* and the small scyliorhinid shark from the coast of Chile originally designated *Scyllium canescens* Günther, 1878.

Pentanchus profundicollis Smith and Radcliffe, 1912, was described from a single Philippine speci-

men as a notidanoid shark intermediate between the Hexanchidae and Chlamydoselachidae but with five gill openings instead of six or seven characterizing the former. It is so close to the scyliorhinids of the genus *Apristurus* in general appearance and details of gross structure, however, that except for the presence of only one instead of two dorsal fins, it would certainly fall within that genus. Regan (1908) was of the opinion that *Pentanchus* belonged in the family Scyliorhinidae and suspected that the absence of one dorsal fin was abnormal or accidental. Although additional specimens are not yet known, the type USNM 70260 is an adult male in fair condition. This specimen, disregarding the number of dorsal fins as a characteristic, does not fit the description of any known species of *Apristurus*. Furthermore, there is no evidence from external examination or the appearance in radiographs that the absence of a dorsal fin (absent from the position occupied by the first dorsal in *Apristurus*) is in any way a result of accident or structural abnormality. Short sections of the vertebral column from the trunk and caudal portions of the type were missing when I examined the type specimen but dissections had been carefully made somewhat off center and should not have affected fin-base vestiges had these been present. It appears to me that the separation of *Pentanchus* and *Apristurus* (as in Bigelow and Schroeder, 1948) is justified and that the two genera are properly to be placed in the family Scyliorhinidae.

Distribution and Segregation

About 58 species in 14 genera are known in the family Scyliorhinidae. With the exception of the Indian Ocean species, *Aetelomycterus marmoratus* (Bennett), cat sharks appear very rarely in warm waters and inhabit shore waters only in the higher latitudes or in comparatively cool-water areas. The common rough-dog, *Scyliorhinus caniculus* (Linnaeus), of Europe, which figures as a laboratory animal in much of the physiological and experimental work on sharks, is an example of a species entering shallow waters. *Cephaloscyllium uter* (Jordan and Gilbert) of the California coast frequents relatively shallow water. In the western Atlantic one species is occasionally taken on the continental shelf north of the Carolinas and another species is said to frequent the shallow shore waters in the vicinity of Cape Horn, but from the

Carolinas to Argentina cat sharks are exclusively inhabitants of the continental slopes. Atlantic American records of *Apristurus* are for the most part from depths of 750 to 1500 meters, and lower latitude records of other cat sharks in the region are from depths of 200 to 750 m.

Along Atlantic American coasts, fewer hauls have been made in depths in excess of 1,000 m. than in shallower water and trawling has been limited in areas where rough bottom topography produced severe gear losses. Deficiencies in the representative quality of the collections are due chiefly to these factors.

Ford (1921), writing about *Scyliorhinus caniculus* at Plymouth, England, noted that there is a curious alternating seasonal predominance of the sexes in adults. In the winter the males were found to be the predominant sex, whereas in the summer the females were the more numerous. Differential preferences by the sexes for depth (and by inference for temperature) were noted by Springer (1960) in shallow-water carcharhinid sharks. This may be true also of some of the cat sharks. The importance of segregation by size as a means for protecting the young against predation by members of their own species is less apparent for cat sharks than for the large voracious carcharhinids, but perhaps is a useful trait. It is of interest in this connection that Ford (1921) reports *Scyliorhinus stellaris* feeding on the smaller *S. caniculus* in the Plymouth area.

Nearly all specimens of cat sharks from the western Atlantic have been taken in trawls. Most of those collected by exploratory vessels were caught in shrimp trawls having 1¾- or 2-inch mesh (stretched). Only the smallest sizes, less than 6 inches, would be able to escape through the meshes; larger cat sharks, over 24 inches long, might sometimes evade the nets.

WESTERN ATLANTIC GENERA

The cat sharks known from the western Atlantic fall into five well marked groups corresponding to the five genera recognized here. Differences of species within genera in the western Atlantic are not great except between the two species of *Halaeburus* reported from Argentina. Of the five western Atlantic genera, one genus, *Apristurus*, is probably cosmopolitan in waters of suitable depth outside of Arctic and Antarctic Re-

gions. *Galeus* is present both in the North Atlantic and North Pacific Oceans but has not yet been found in the Southern Hemisphere if recognition is accorded Whitley's genus *Figaro* (1934). *Schroederichthys* is restricted to the Caribbean and tropical Atlantic. Western Atlantic members of the genus *Scyliorhinus* form a compact infrageneric group differing less from one another than from species found in the eastern Atlantic or in the western Pacific. *Halaeburus*, as understood here, includes species from the Indo-Pacific region and the Southern Hemisphere.

The area of marine situations suitable to most of the species of cat sharks is very small in comparison to the total ocean area. *Apristurus*, which on Atlantic American coasts is found most commonly at depths from 750 to 1,500 m. and may range into deeper water, occurs over a much greater geographical area than species of other genera, possibly being present in ocean basins of moderate depths. Figure 1 showing the extent and distribution of bottom along the Atlantic coast of temperate North America at depths between 100 and 500 fathoms illustrates the rather narrow bands in some areas to which cat sharks may be restricted. Along tropical and subtropical western Atlantic continental slopes, the ranges of cat sharks other than *Apristurus* are extremely narrow bands.

The largest of the western Atlantic species probably do not ordinarily attain a length as great as 80 cm., and the smaller species (one species of *Scyliorhinus*, one *Apristurus*, the three American *Galeus*, and *Schroederichthys*) probably do not exceed 50 cm. Some eastern Atlantic and South African species are larger. *Scyliorhinus stellaris* (Linnaeus) of the eastern Atlantic reaches a length of 150 cm. in the Atlantic but only about 75 cm. in the Mediterranean (Tortonese, 1956). Smith (1949) gives maximum sizes of 4 feet (122 cm.) or more for *Scyliorhinus capensis* (Müller and Henle) and *Conoporoderma africanum* (Gmelin) of South African coasts.

At the present time, a revision of the family involving a review of generic or family classifications using some of the more advanced modern methods that are available is impractical because insufficient descriptive data exists for most named species. Furthermore, it is very likely that a rela-

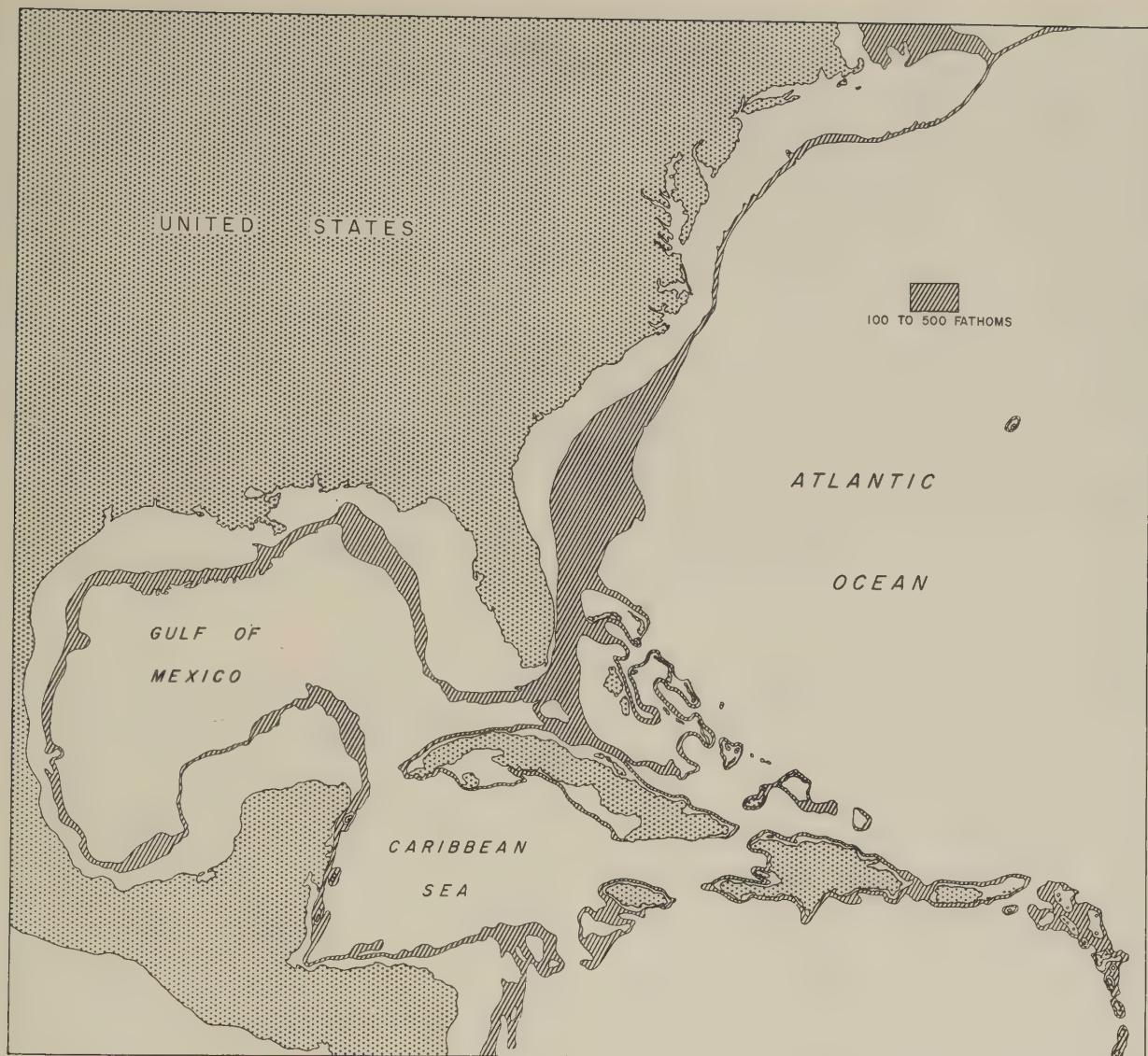


FIGURE 1.—More than 95 percent of the specimens of scyliorhinids from the western North Atlantic available for study have been collected within the 100- to 500-fathom (183- to 914-m.) depth range shown here.

tively large number of unnamed species exist, undescribed not because their differences from other species have not been recognized, but undescribed because examples have not yet been caught. For this study, more than half the specimens have been collected within the past five years.

To anticipate in detail the needs of future studies is presumptuous, but some of the characters of the genera of the cat sharks of the western Atlantic that have been little used in orthodox or classical studies seem worth discussion even though these cannot be fully utilized in reaching

taxonomic decisions in this geographically limited study.

Color and color pattern

Western Atlantic cat sharks fall in two groups with respect to color pattern. All *Apristurus* are nearly uniform in color, and preserved specimens are either black or dark brown of various shades but with no tendency to the formation of any pattern. A few specimens that I have seen brought to the surface from hauls in the northern Gulf of Mexico were uniform black, but these became either very dark gray or dark brown after

preservation. Areas of skin not covered by denticles, around the gills for example, remained darker; and edges of fins, where denticles are sometimes either more numerous or are absent, became a different shade of brown or black than the rest of the body surfaces after preservation. The material examined suggests that there is no diagnostic significance to brown or black color in museum specimens because color changes variously after preservation.

Excepting *Apristurus*, all Atlantic American cat sharks now known are somewhat darker above and lighter below, and furthermore, all have some pattern of spots, blotches, or lines on the dorsal surfaces, either lighter or darker than the background color. This does not pertain outside the western Atlantic where the genus *Galeus*, for example, is represented by some species without markings, at least as adults, and other genera, *Parmaturus* for example, are represented by species that are uniformly dark.

The two species of western Atlantic *Galeus* have color patterns that differ in intensity among the three forms but show more resemblances to one another than to color patterns in any other genus. The patterns in *Galeus* are complex and difficult to describe. Because pattern differences in this genus are obscured by differences in intensity of pattern, they are of low value in field identification and other characters are not only more easily described but also may be more reliable.

Species of the three other genera as represented in the western Atlantic, *Scyliorhinus*, *Schroederichthys*, and *Halaelurus*, have essentially similar basic color patterns but have diagnostically useful modifications of the basic patterns. As indicated by the few species of which juvenile examples are available, and in its simplest and most persistent form, the basic pattern consists of a series of seven dorsal saddles or blotches. Depending upon species, either more saddles may be present in intermediate positions or some of the main saddles may be obscure.

A parallel development of pattern in *Scyliorhinus torrei* Howell-Rivero and *Schroederichthys maculatus* (one of the new species described here) illustrates this. Both species have the seven dorsal saddles appearing in some individuals but generally more prominent in the young. In adults of both species, however, the saddles may

become quite indistinct with a partial substitution of a pattern of small white spots on a tan background color. The tan color here is the color in life and is not brought about by preservation. The saddles seem to become more distinct with preservation. In life or when freshly preserved the two species are so similar in appearance of the color and pattern that the rather great structural differences may be overlooked easily.

Variation in pattern within species in the material at hand is moderate and reasonably well defined. Figure 2A shows a rather extreme example of the absence of full development of a reticulate pattern characteristic of *Scyliorhinus retifer* (Garman), whereas figure 2B shows a specimen with the reticulate pattern fully, but not uniformly, developed. Although this pattern is variable, it can be distinguished readily from patterns made up of discrete black spots or white spots.

Reproduction

Most cat sharks lay eggs in cases which, when first laid, are impervious and sealed against the entry of seawater. During development of the embryo, slits appear in corners of the egg cases to permit a flow of sea water through the egg case. Tendrils, one from each of the four corners of the egg case, attach it to objects on the bottom when the eggs are laid.

In addition to information on the egg laying habits of *Apristurus riveri*, available records and material show that *Scyliorhinus retifer* and *Schroederichthys maculatus* lay eggs. No positive information is at hand for other western Atlantic species, but an egg case with developing embryo (fig. 3) may be presumed to be either *Scyliorhinus meadi* or *S. torrei* on indirect evidence of locality.

The genus *Galeus* is represented in the eastern Atlantic, including Icelandic waters, by four species among which are two little-known forms without markings or color patterns; these were described from specimens from the Hebrides and from Iceland. The remaining eastern Atlantic forms include *Galeus melastomus* Rafinesque, an egg layer, and *Galeus polli* Cadenat, an ovoviviparous species that retains eggs in the oviduct until after the egg shell has been absorbed and after the embryo has completed absorption of the yolk sac. No positive evidence has been found to

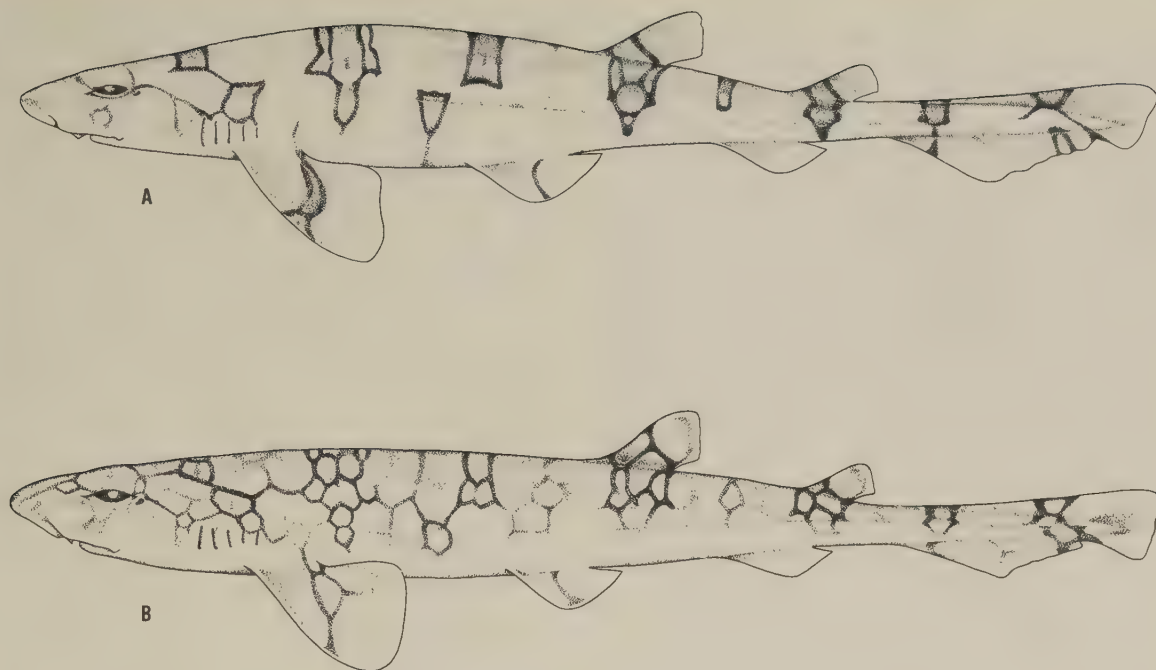


FIGURE 2.—*Scyliorhinus retifer* (Garman): A, Drawn from a 465-mm. female; B, drawn from a 380-mm. female. Both specimens collected in 365–385 m. off Pensacola, Fla. The upper figure shows a specimen with seven major saddles but with the addition of one intermediate saddle between the two dorsal fins. The darker reticulations in the lower figure can be seen to delineate seven major saddles.



show whether or not western Atlantic species produce living young. Probably both western Atlantic species are ovoviviparous. No shelled eggs have been found in oviducts of the many adult female specimens that have been examined, and no unidentified egg cases small enough to belong to *Galeus* have been seen.

Claspers and clasper siphons

Leigh-Sharpe has proposed that more consideration be given to the structure of the claspers and clasper siphons or clasper glands in taxonomic studies of elasmobranchs. In a series of papers published between 1920 and 1926 he described these

FIGURE 3.—Egg case of a cat shark collected off Cape Kennedy, Fla., showing a developing embryo within its entirely transparent and colorless case and showing the characteristic method of attachment of the case. The degree of transparency of the egg case, the shape, and the nature of surface markings on it vary with species. Transparent egg cases which may be quite free from color when fresh may become brownish after storage in alcohol. The embryo color pattern and the site of collection of the egg case suggests that it is *Scyliorhinus maclei*. Drawn from an egg case approximately 1.4 by 4.0 cm. exclusive of tendrils.

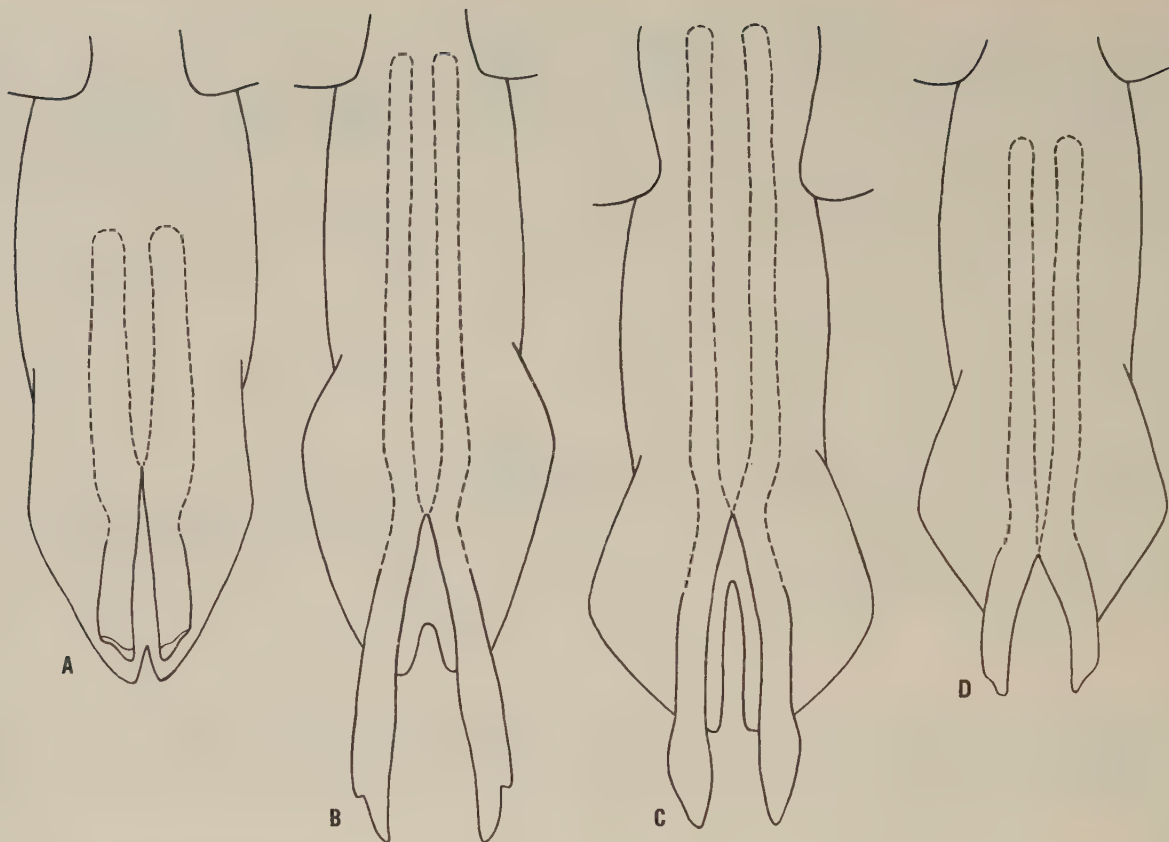


FIGURE 4.—Diagrams showing general shapes of claspers and clasper siphons in adult male cat sharks: A, *Scyliorhinus torrei* and B, *Galeus arae*, both from the Florida Straits; C, *Schroederichthys maculatus* from the western Caribbean; and D, *Apristurus riveri* from the southwestern Caribbean. Each drawn to scale but scales are unequal.

structures in some scyliorhinids in detail (Leigh-Sharpe 1920, 1922, 1924, 1926a, and 1926b). In practical application for taxonomic studies, however, there is some difficulty because of inadequate series of specimens. Of the 15 western Atlantic scyliorhinids treated here, for example, adult male specimens were not available for 6 species.

Diagrams outlining the general size and shape of claspers in relation to the pelvic fins and outlining roughly the extent of the clasper siphons are shown in figure 4 for representatives of four western Atlantic genera. No important differences in gross examination were noted among adult males of the two species of western Atlantic *Galeus*. Supplementary examination of a few adult male *Galeus* from the eastern Atlantic and from the Pacific failed to reveal substantial differences in clasper structures within the genus excepting the presence of hooks on specimens of western

Atlantic species examined and the absence of these on the only eastern Atlantic adult male available. The available material is insufficient to show whether clasper structures of western Atlantic scyliorhinids are useful in the diagnosis of species, but from a necessarily cursory review it appears that they might be quite useful as generic characters.

Hooks were present on claspers of the species of *Galeus* but were absent on *Apristurus* and *Schroederichthys* and from the claspers of western Atlantic *Scyliorhinus* examined. Hooks were not found on a clasper of one *Galeus melastomus* from the eastern Atlantic.

The denticles on the surfaces of claspers in all of the specimens examined have their points directed forward toward the base of the clasper. The reversal of direction of the denticles is noted as occurring in *Scyliorhinus stellaris* (= *Scyllium*

catulus) by Leigh-Sharpe (1920) and apparently is a feature common to all galeoid sharks but not to sharks of other suborders.

Shape of body and fins

The caudal axis in the family Scyliorhinidae is little elevated and, excepting adults of *Scyliorhinus*, the overall shape of western Atlantic species is slender. One genus, *Schroederichthys*, has a very elongate postpelvic trunk region.

The length of the body cavity relative to the overall size of the fish (volume) differs considerably in the four genera found in the tropical and northern Atlantic. This difference is reflected in the size of the liver and it appears likely that with sufficient material for study it would be found that liver characteristics would be useful as taxonomic criteria. The general shape of the liver is shown in figure 5.

A series of Pacific *Apristurus brunneus* examined in comparison with *Apristurus riveri* from the Atlantic show some apparently constant differences in liver shape. In *A. brunneus* the liver is larger and in most specimens the right and left posterior lobes are united for most of their length,

excepting only that part just anterior to and extending past the cloaca. In *A. brunneus* the liver almost completely covers the visceral cavity when viewed from the ventral aspect. Only the falciform ligament and the rectum are visible in addition to the liver when the body cavity is opened ventrally. Thus it would seem from casual inspection that large ripe eggs from the ovary located under the liver when viewed from the ventral aspect (only right ovary functional in scyliorhinids) would have to make a remarkably long or tortuous journey to reach the opening of the oviducts.

It may be significant in indicating possible derivation of the orectolobids which have quite short snouts with reduced or absent rostral cartilages, that western Atlantic *Scyliorhinus* and *Halaelurus* have relatively short snouts, *Schroederichthys* has a moderately short snout, but both *Galeus* and *Apristurus* are long-snouted. Associated with the long snouts of *Galeus* and *Apristurus* is the comparatively greater prominence of the external pores for the Ampullae of Lorenzini. The extensive pore system of the Ampullae of Lorenzini in *Apristurus* may be associated with its habitat

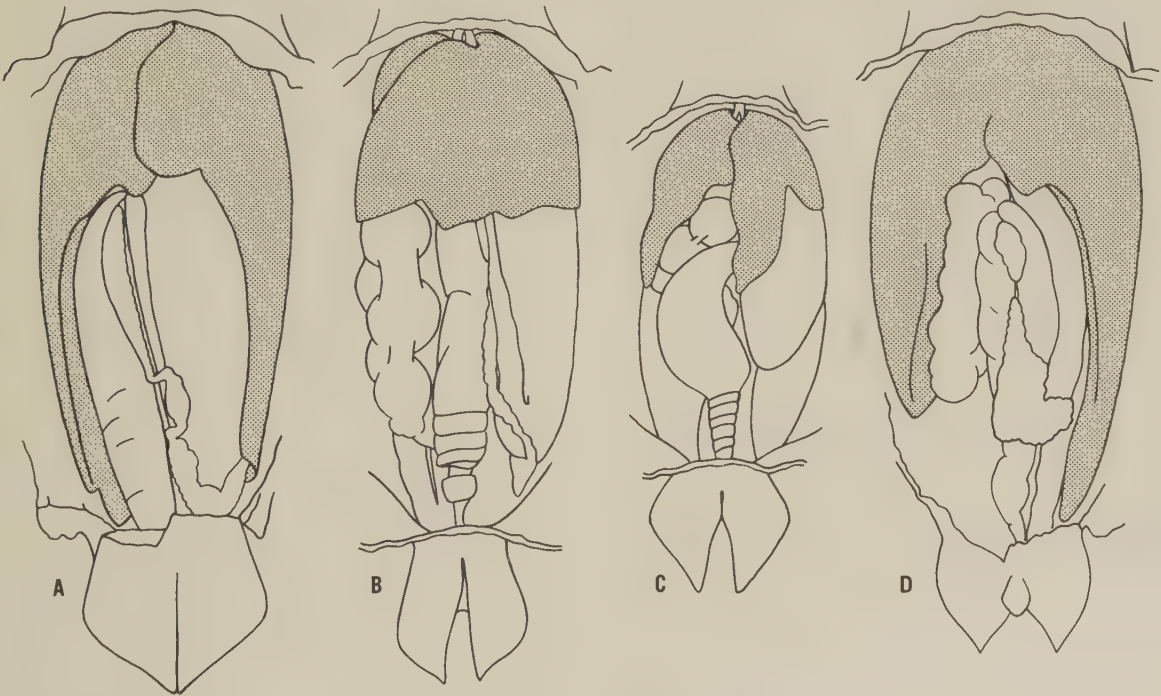


FIGURE 5.—Diagrams of the arrangement of visceral organs showing liver shapes (stippled areas) in representatives of four western Atlantic genera: A, *Scyliorhinus retifer*; B, *Galeus arae*; C, *Schroederichthys maculatus*; and D, *Apristurus riveri*.

which is in comparatively deeper water than any of the other cat sharks. Pineal windows were not seen in the specimens of *Apristurus* or any other cat sharks examined. Among sharks, these are consistently present in the squaloid genus *Etmopterus*, members of which are black.

Dermal denticles

The size, arrangement, and structure of dermal denticles are often quite useful characters for practical problems in identification of sharks. Ordinarily the typical dermal denticles used in descriptive accounts of species are those from a lateral surface near the first dorsal fin but below the mid-dorsal line. Here, unless some specific location is indicated, denticle descriptions are from denticles taken at a point about halfway along a line between the axil of the pectoral fin and the origin of the first dorsal fin. In some instances, differences in the denticle structure are the most reliable and definite means of determining species. For example, *Squalus blainvillei* is readily distinguished from *Squalus cubensis* by great differences in denticle shapes. Among scyliorhinids of the western Atlantic, denticle differences are either less well marked or need qualification as to location or as to the size or age of the specimens involved in comparisons.

In *Scyliorhinus retifer* the denticles increase in size as the shark becomes larger and the denticles change somewhat in shape. In some sharks it is evident that the number of denticles increases as the shark grows large, but in the series of *S. retifer* examined, positive evidence of an increase in the number of denticles with increasing size was not apparent in a cursory examination. The general aspect of a section of skin surface with denticles is shown in figure 6.

In *Scyliorhinus retifer* denticle shapes on different parts of the body vary and the variation fol-

lows a pattern more or less characteristic of all galeoid sharks. On the ventral surfaces the denticles have much less prominent ridges and the lateral points are generally absent. On leading edges of fins the denticles are usually smoother and flattened so that there are no projecting points. On the head and especially those parts of the head used sometimes for bumping objects, the denticles are somewhat shorter with thicker edges or points.

Denticles of *Galeus* and *Apristurus* follow this plan to a less marked degree. The denticles of ventral surfaces are about the same shape as those of the dorsal surfaces, but their construction is lighter.

Specialized dermal denticles forming a crest along the upper margin of the caudal fin are found on all species of the genus *Galeus*, varying slightly among species but probably not sufficiently to be used in practical field identification. The genus *Figaro* Whitley has been described from Australian waters and differs in having the specialized scales on both the upper and lower margins of the caudal fin. The eastern Pacific genus *Parmaturus*, quite unlike *Galeus* in many respects, has a denticle crest on the upper caudal fin margin.

Although not having a definite crest, *Apristurus profundorum* has several rows of compactly arranged, imbricate denticles along the upper margin of the caudal fin. The body and sides of the fins in that species are quite sparsely clothed with denticles which are nearly erect.

The young of *Scyliorhinus caniculus* and *S. stellaris* have a series of enlarged scales, one series on each side of the middorsal line extending from the shoulder area back to the first dorsal fin. According to Ford (1921), these scales are visible in embryos of *S. caniculus* taken at Plymouth, England, when the embryos are 44 mm. long. They persist for a short time after hatching, but similar scales are present on *S. stellaris* and may still remain in place until the sharks are over a foot long.

Enlarged scales are present on an embryo (fig. 8) presumed to be *S. retifer*. They are not visible in specimens of 150 mm. or more, but on specimens of newly hatched *S. retifer* they are represented sometimes by a series of scars. Enlarged denticles in a similar position but widely spaced are present in *Halaehururus* from Chile, usually surrounded by a ring of somewhat modified smaller denticles. Series of enlarged denticles are present on both

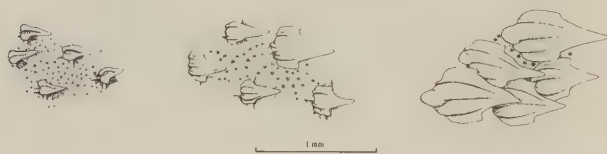


FIGURE 6.—Dermal denticles from a series of female *Scyliorhinus retifer* from the Gulf of Mexico. Left from a specimen 175 mm., center from a 295-mm. specimen, and right from a 465-mm. specimen. Camera lucida drawings to the scale indicated.

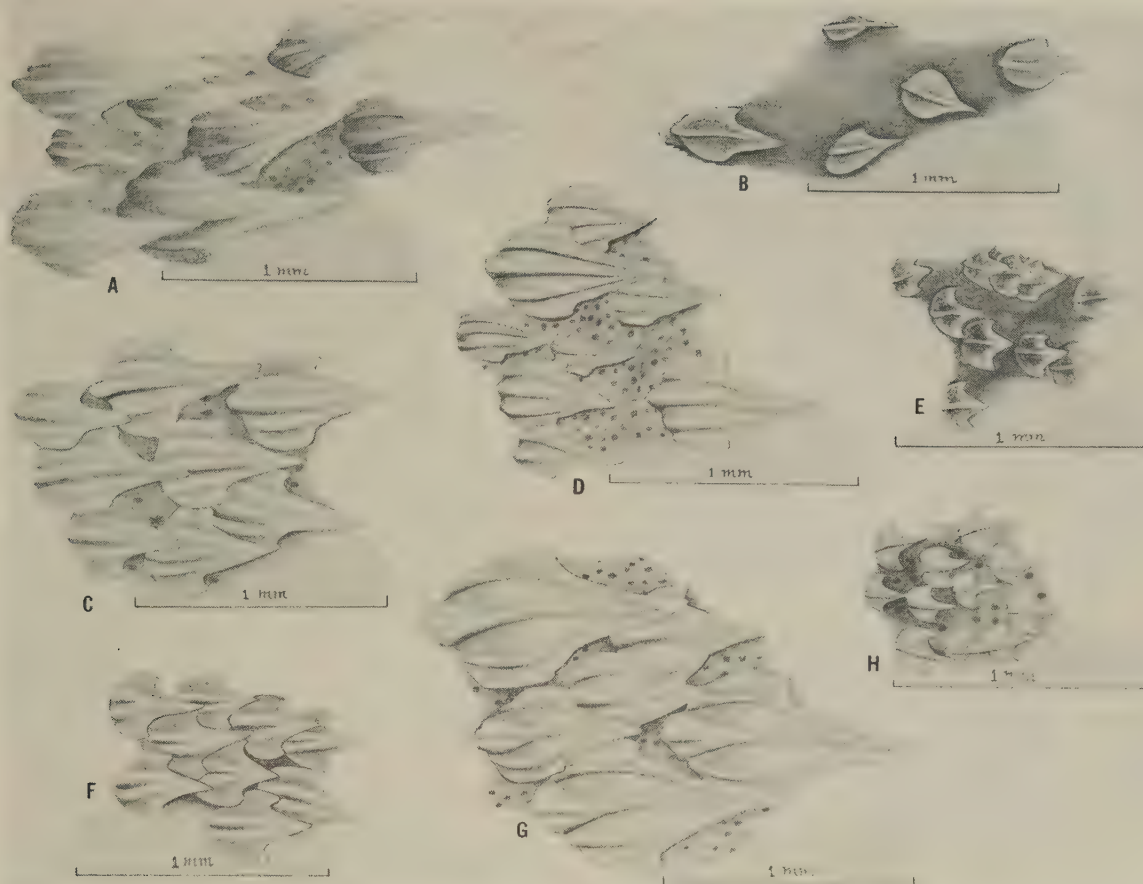


FIGURE 7.—Camera lucida drawings of denticles from some western Atlantic catsharks: A, *Scyliorhinus meadi* from 264-mm. immature male; B, *Apristurus profundorum* from 380-mm. immature female; C, *Scyliorhinus torrei* from 243-mm. adult male; D, *Scyliorhinus hesperius* from 296-mm. immature male; E, *Apristurus riveri* from 450-mm. adult female; F, *Schroederichthys maculatus* n. sp., from 295-mm. adult female; G, *Scyliorhinus retifer* from 410-mm. adult male; H, *Galeus arae* from 287-mm. immature female. Note: Denticles of *Apristurus profundorum* are more erect over most of the body surfaces than shown here, their points projecting almost perpendicularly from the plane of the skin surface.

sides of the middorsal line of a 160-mm. specimen of *Cephaloscyllium uter* from Monterey Bay, Calif.

Teeth

The teeth of scyliorhinid sharks are small, most commonly with a larger central cusp having one or more smaller lateral cusps on each side. In some species of *Apristurus* the teeth nearer the corners of the mouth may have many cusps (as many as nine have been noted) with the central cusp but little higher than adjacent ones. In *Atelomycterus* from the Indo-Pacific, the cusps of some of the teeth near the corners of the mouth are much reduced and the rows are fitted so close to-

gether as to form an almost smooth grinding surface.

Except for specimens of *Apristurus*, the tooth form does not vary greatly in the scyliorhinid specimens examined from the western Atlantic and it is probably impractical to attempt to distinguish most species from teeth alone. Western Atlantic *Apristurus*, as a general rule, have teeth with more cusps and, in some *Apristurus*, crowding of some of the lateral cusps in front of the central cusp (see fig. 9D) is frequent.

In *Apristurus riveri* the most extreme tooth dimorphism yet reported for sharks occurs. The two adult males that constitute our entire series of

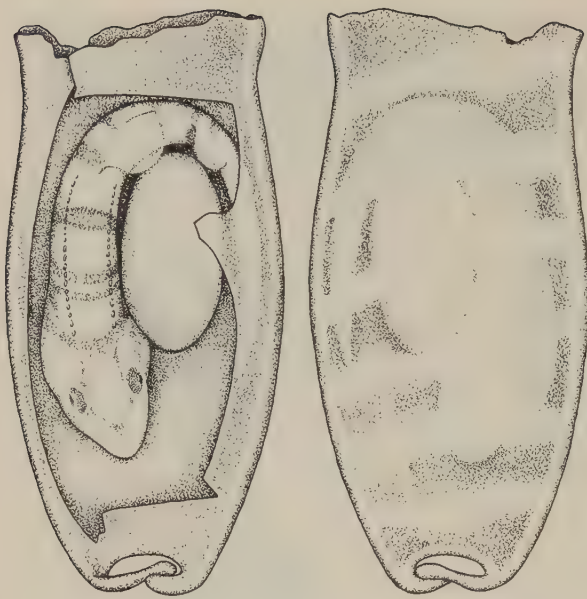


FIGURE 8.—Egg case of a cat shark collected from 100 fathoms off the coast of North Carolina, showing an embryo with the two series of enlarged denticles that characterize the young in some species of scyliorhinid sharks. Presumably this is an embryo of *Scyliorhinus retifer*. The somewhat opaque white banding in the shell has not been reported previously and may not always be evident in egg cases of the species.

males of that species not only have teeth twice as long as the teeth of females of comparable size but the teeth of the males are also quite different in shape from those of the females, with lateral cusps entirely absent on the teeth of the central part of the jaws. A few teeth with lateral denticles or cusps are present among the last few rows toward the angles of the jaws.

This degree of dimorphism illustrated by the accompanying diagram (fig. 10) does not occur in the other species of *Apristurus* that are represented by sufficient material to check. The teeth of males of the Pacific species, *Apristurus brunneus*, are somewhat larger than the teeth of females of comparable size, but there is no important difference in tooth shape. No significant dimorphism is present in *A. profundorum*, *A. indicus*, or *A. laurussoni*.

It is suggested that the modification in teeth would function effectively to hold the female, perhaps by the pectoral fin, during copulation.

With reference to *Halaehurus* from Patagonia, Vaillant (1891) states that one finds great vari-

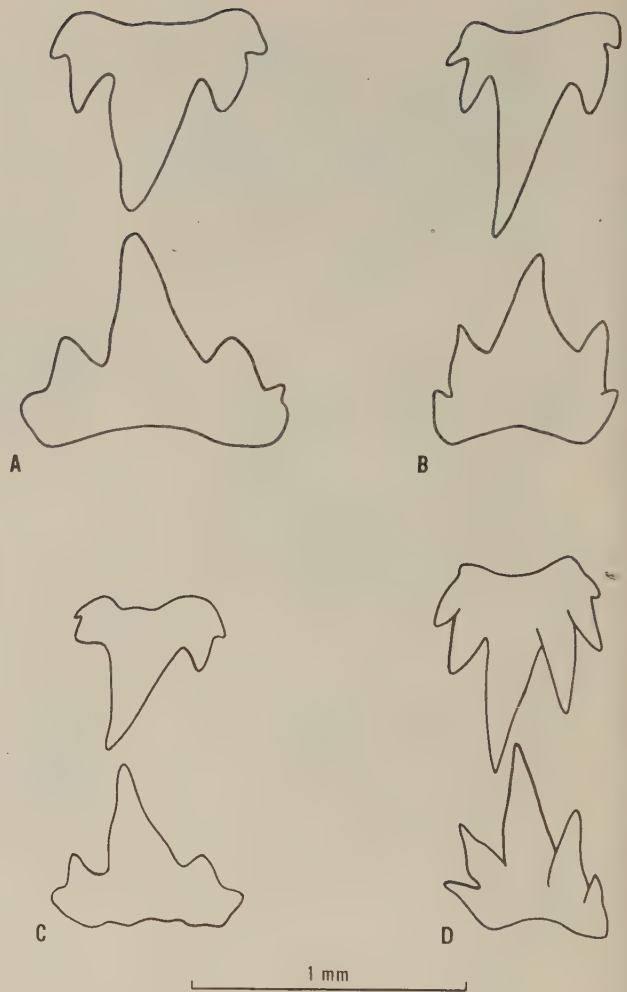


FIGURE 9.—Camera lucida outlines of teeth from upper and lower jaws, shark's right side, fifth lateral row counting from the symphysis: A, *Scyliorhinus hesperius*, a 272-mm. female; B, *Galeus arae*, a 365-mm. male; C, *Schroederichthys maculatus*, a 220-mm. male; and D, *Apristurus indicus*, a 430-mm. female.

ation in the teeth of the lower jaw with differences following size and perhaps sex. Also in a table of differences between *Scyllium bivium* and *S. chilense* (*Scyllium*=*Halaehurus*), Vaillant notes that the lower jaw teeth of *bivium* are not very small and are either without lateral cusps or with lateral cusps not very distinct, whereas the teeth of the lower jaw in *chilense* are very small and have no lateral points. In spite of complications of nomenclature and contradictions in the literature, it is obvious that South American *Halaehurus* exhibit a transition in tooth form. A more thorough study is necessary to determine whether



FIGURE 10.—Camera lucida outlines of teeth of 405-mm. adult female *Apristurus riveri* (left) compared with same scale outlines of teeth of 430-mm. adult male

(right) both specimens from 860- to 914-m. depth off the Caribbean coast of Panama.

changes in tooth form occur at sexual maturity or whether several species with different tooth forms are involved with or without changes during growth. South American *Halaehurus* (not including the deeper water form *Scyllium canescens* Günther) shows a trend toward development of spike dentition in the lower jaw. Spike teeth in the lower jaw and cutting teeth in the upper jaw always characterize species of the larger and more specialized galeoids wherever differences in apparent function between upper and lower jaws exist. In contrast, in the notidanoids and squaloids it is the upper jaw that has spike teeth.

It has been customary to express a tooth formula for extant sharks simply as the number of teeth in the upper jaw over the number of teeth in the lower jaw. In sharks having only one functional band of teeth, the counts are rather easily determined. In *Carcharhinus leucas*, for example, this would be 27/25 where 27 is the num-

ber of teeth on the upper jaw and 25 is the number on the lower jaw. A refinement of this kind of formula, used for example by Bigelow and Schroeder (1948), breaks down the count to indicate the number of very small teeth at or near the jaw symphyses. In *C. leucas* such a count might be expressed as 13+1+13/12+1+12, where 13 is the number of teeth on each side of the upper jaw, 12 the number on each side of the lower jaw and 1 represents the number of very small teeth at the symphysis. Leriche (1905) developed a classification of the various types of teeth found in the jaws of fossil sharks which permits the use of a more descriptive and meaningful formula to express conditions found in various species. Applegate (1965) has proposed some modification of the Leriche system and an extension of its use to extant species. This system has obvious merits although its formulas are perhaps less informative about scyliorhinids than about species in most

other shark families. No attempt has been made to use it here because of this and because only about half the scyliorhinid genera are being reviewed.

Strasburg (1963), in discussing tooth replacement in a squaloid species, *Isistius*, used the terms independent dentition, alternate overlap, imbricate overlap, and mixed alternate and imbricate overlap to describe the arrangement of teeth in a transverse band and to distinguish these arrangements from the modified imbricate overlap found in *Isistius*. He found no pure alternate dentition in the species he examined, but these did not include a scyliorhinid.

In scyliorhinids several transverse series of teeth are functional. For the purposes of this discussion a series of teeth is defined as a file or array of teeth along a single line running parallel to the jaw cartilage axis from one corner of the jaw opening to the other. A row of teeth on the other hand is defined as a file of teeth in a line extending from a germinal area on the inner surface of the jaw to the outer rim of the jaw or lip. Rows of teeth are frequently, but not always, arranged in a line on a plane perpendicular to the axis of the jaw cartilage.

In all scyliorhinid sharks several series of teeth are functional, and in addition two or more series of developing teeth are present along the inner side of the jaw. The developing teeth are covered there by the lining of the mouth which forms a protected space in which tooth buds form. In *Scyliorhinus*, *Galeus*, and *Schroederichthys* four or five functional series are usually present in each jaw and in *Apristurus* five or six functional series. Impressions or scars of tooth bases are often visible at the outer ends of tooth rows. If two series are considered together as one band, the arrangement is alternate, the teeth in the outer series being present in half the tooth rows with their bases overlapping the alternately occurring teeth of the next functional series. The teeth of all specimens of scyliorhinids examined were somewhat crowded with a considerable degree of overlap (see fig. 11). Alternate dentition with less crowding is to be found in some sharks of other groups. The arrangement of teeth which, following Strasburg (1963), would probably be called modified alternate dentition if found in *Pristiophorus*, but with less crowding has a quite different appearance from

the typical arrangements in scyliorhinids. In *Pristiophorus* (fig. 12) the number of rows of teeth are readily counted, and no confusion results from the appearance of diagonal files of teeth.

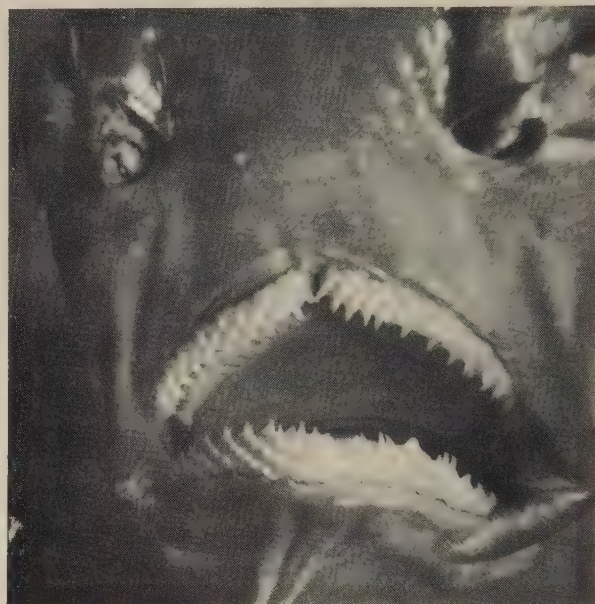


FIGURE 11.—Head of a 430-mm. adult male *Apristurus riveri* showing diagonal files of teeth in the lower jaw at the left side of the photograph. Dentition in this specimen is alternate throughout. Reflections from base of some of the teeth appear in the photograph to depict accessory cusps, but in reality none are present on teeth that are shown in the photograph.

The presence or absence of a separation of the teeth of one side of a jaw from teeth of the other side by a band of fleshy material seems to be a variable in the scyliorhinid specimens examined. Many specimens of *Apristurus* have such a separation either in the upper or lower jaw or both, whereas some do not. Furthermore this variation occurs in series of the same species. The extent to which this variation may be the result of stretching of ligaments at the symphysis has not been determined.

The number of tooth rows in some scyliorhinids is difficult to count for a variety of reasons. The teeth are small, and toward the angles of the jaws low-crowned multicusped teeth are not clearly defined. The teeth are crowded, and in a few specimens, or perhaps a few species, the arrangement of the teeth is not a simple alternate arrangement but is mixed. Similarities between the cat sharks,

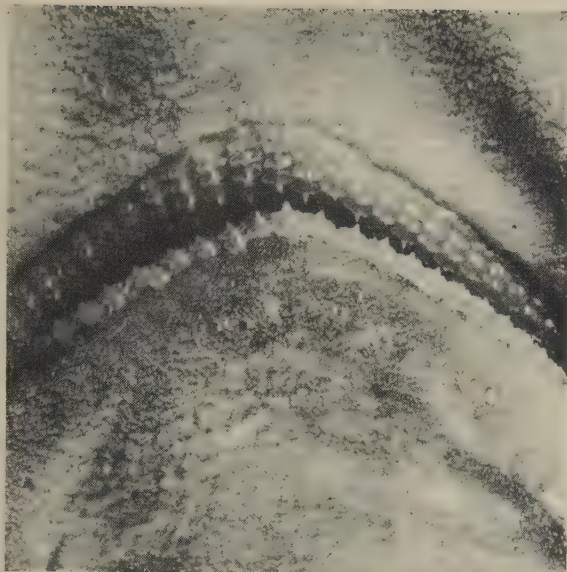


FIGURE 12.—Teeth of the saw shark, *Pristiophorus schroederi* (Pristiophoroidea), showing a modified alternate tooth arrangement differing from the arrangement found in the *Scyliorhinidae* (Galeoidea) chiefly in the lesser degree of crowding. Photograph by Los Angeles County Museum.

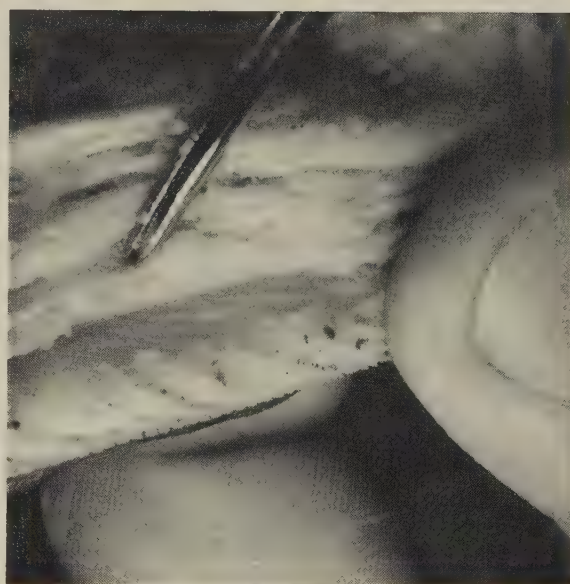


FIGURE 13.—Upper photograph showing diagonal files of teeth in the lower jaw of the type specimen of *Pseudotriakis acrages* Jordan and Snyder (SU 12903). Lower photograph, same jaw rolled outward with the tooth germinal area exposed and showing continuation of the files diagonally on the dental lamina where they become progressively smaller and softer to the point of their apparent origin.

Scyliorhinidae, and the false cat sharks, Pseudotriakidae, already have been noted. The upper and lower jaw teeth of *Pseudotriakis microdon* Bocage and Capello are illustrated in Bigelow and Schroeder (1948) and are described and discussed in more detail by Jaquet (1905). The arrangement of teeth in the lower jaw in *Pseudotriakis* and *Apristurus* have some similarity in appearance due to the rather well defined diagonal files of teeth. Gross examination of the type specimen of *Pseudotriakis acrages* Jordan and Snyder (SU 12903) shows the diagonal files of lower jaw teeth continuing widely separated, but with the teeth within a file quite close together, back to the germinal area (see fig. 13). This appears to indicate a diagonal movement of the teeth from the area of budding into the functional position, but such an explanation is superficial. A study of the comparative histology of the developing teeth in several families of sharks should prove helpful in indicating relationships.

NUMBER OF VERTEBRAE

Vertebrae were counted from radiographs of specimens of the family, but the diplospondylous vertebrae near the tail tips were difficult to count.

Furthermore, in some radiographs it was not possible to determine whether all of the terminal vertebrae appeared. Since it was always possible to

count the number of monospondylous vertebrae with confidence, only these counts are given here (table 1).

The series reported here is too small for definitive use, but is sufficient to give promise that a more comprehensive study would be helpful in species diagnosis. Several kinds of interpretive factors may require consideration in a more comprehensive study. Some variation in meristic characters would not be surprising in a sample collected over a large geographical range. In our series of 33 counts from *Apristurus indicus*, the counts vary from 35 to 41, and localities of capture range over 20 degrees in latitude. In the series of 25 counts for *Apristurus laurussoni* a single count, higher than the cluster, is the count for the holotype, taken about 20 degrees north of any of the other specimens of the series.

The reliability of counts of vertebrae for purposes of numerical analysis or for identification is reduced because of abnormalities occasionally present. In the distribution of counts in 34 specimens of *Schroederichthys maculatus*, for example, where 33 are clustered but one count is somewhat apart, the high count in this specimen appears to be attributable to an uneven transition to diplospondyly. Here a few dispoisondylous vertebrae appeared well forward in the trunk region.

MORPHOMETRICS

The conventional ways to measure sharks are comprehensively illustrated by Garrick and Schultz (1963, figs. 1A and 1B), and this system of measurement is used here insofar as possible. Unfortunately measurements very useful for some sharks are difficult to apply to others. In the scyliorhinids, for example, the axis of the caudal

fin is not perceptibly elevated and the point at which the upper lobe of the caudal fin begins is merely an estimate. The fins of scyliorhinid sharks, especially *Apristurus*, are soft and are generally rounded or lobelike structures making fin measurements difficult to define.

Most diagnostic accounts of scyliorhinids rely greatly upon morphometrics as key characters to separate species or genera. These characters are at least accessible and their use does not require a microscope. As applied to scyliorhinids, however, some kinds of comparative measurements seem to be particularly unreliable.

In comparing fin sizes, for example, the statement that the length of the base of the anal is 4 times the length of the base of the first dorsal fin in one species, but only 2½ times the length in another species, introduces a variety of difficulties in practical application. Precise measurements of the length of fin bases are not easily made because of the gradual slope of the forward end of the fin. This is sometimes complicated by the distortion or shriveling of the specimen in preservation. The lengths of fin bases may vary independently. Thus a comparison that seems quite clearly to differentiate species when some specimens are compared may be quite inadequate for other specimens.

In scyliorhinids there are occasionally specimens having much longer gill slits on one side than on the other, and gill slits are especially subject to distortion in length or even in position by preservation.

The ease with which data on measurement can be communicated and the difficulty of correctly and adequately describing shape seem to have led to overemphasis of measurements and less than

TABLE 1.—Frequency of occurrence of various numbers of monospondylous vertebrae in some western Atlantic cat sharks

Species	Number of monospondylous vertebrae																					
	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	38	49	
<i>Scyliorhinus retifer</i>											2	5	8	7	1							
<i>Scyliorhinus boa</i>												4		1		1						
<i>Scyliorhinus meadi</i>															1							
<i>Scyliorhinus hesperius</i>											2	3	2	1				1		2	1	
<i>Scyliorhinus torrei</i>		1	3	2	3	2																
<i>Schroederichthys maculatus</i>	6	22	3	2			1															
<i>Schroederichthys tenuis</i>				1		1																
<i>Galeus arae</i>					1	12	14	8	2													
<i>Galeus cadenati</i>					4	7	1	1														
<i>Apristurus profundorum</i>					1	1	4	1														
<i>Apristurus riwieri</i>		1	6	3																		
<i>Apristurus indicus</i>							2	1	4	13	8	4	1									
<i>Apristurus laurussoni</i>									3	2	8	7	4		1							

desirable treatment of other characters. Measurements remain useful in description, but some better balance and the use of a large number of characters, including some that can best be described in illustrations, seems desirable and perhaps necessary for a revision of the family.

KEY TO GENERA OF WESTERN ATLANTIC SCYLIORHINIDAE

The following key to western Atlantic genera is sufficient for their separation, but the degree of difference between them is better illustrated in the chart given as table 2.

KEY TO WESTERN ATLANTIC GENERA OF SCYLIORHINIDAE

- 1A. Color uniform black or dark brown except for lighter or darker fins in some species----- *Apristurus*
- 1B. Color variegated with spots, blotches or saddles, lighter below----- 2A or 2B
- 2A. Crest of enlarged denticles along upper edge of caudal fin ----- *Galeus*
- 2B. No crest of enlarged denticles along upper edge of caudal fin----- 3A or 3B
- 3A. Tip of snout to anus about one-third of total length ----- *Schroederichthys*
- 3B. Tip of snout to anus about three-eighths to one-half of total length----- 4A or 4B
- 4A. Labial fold present only along lower jaw ----- *Scyliorhinus*
- 4B. Labial fold around corner of mouth extending along both jaws----- *Halaelurus*

Genus *Scyliorhinus* Blainville 1816

Type species—*Squalus canicula* Lacépède, designated by Gill, 1861.

Western Atlantic species of *Scyliorhinus* differ from one another primarily in color pattern although one species, *Scyliorhinus torrei*, is much smaller than the other four and another, *S. meadi*, has more erect and slightly larger denticles than any of the others, giving it a somewhat shaggy appearance.

Scyliorhinus torazame (Tanaka) [= *Halaelurus rudis* (Pietschmann)] of Japanese waters, *S. stellaris* (Linnaeus) and *S. canicula* (Linnaeus) of eastern North Atlantic waters, and *S. capensis* (Müller and Henle) of South Africa and the eastern Indian Ocean, all differ in details of color pattern from one another and from American species. No eastern Pacific species are known. Specimens of *S. torazame* that have been examined have the pelvic fins united to a point somewhat nearer their tips than most specimens of the American species and have enlarged and nearly erect dorsal denticles rather regularly scattered on dorsal surfaces among more numerous smaller ones; but the larger denticles are not arranged in rows, and the character seems to be variable. The American species, excepting *S. torrei*, have slightly longer snouts than other species. The European *S. canicula* has the two nasal flaps united at the midline, and the confluent flap reaches the edge of the upper lip. As for other members of the genus, nasal flaps are often smaller in examples of the American species than in others, but specimens can be selected from series of *S. stellaris* and *S. retifer*, for example, in

TABLE 2.—Characteristics of genera of the family Scyliorhinidae as present in western Atlantic species

Characters	<i>Scyliorhinus</i>	<i>Halaelurus</i> (shortest snout)	<i>Galeus</i>	<i>Schroederichthys</i>	<i>Apristurus</i> (longest snout)
Color-----	Variegated; dorsal saddles present but sometimes obscure.	As in <i>Scyliorhinus</i> -----	Plain color or variegated but without well-marked saddles.	As in <i>Scyliorhinus</i> -----	Black or sometimes brown; color uniform without strong markings.
Caudal crest-----	None-----	None-----	Present-----	None-----	Absent except partly developed in one species.
Labial grooves-----	Weak; present only on lower jaw.	Strong on both jaws-----	Moderate on both jaws--	Moderate on both jaws..	Strong on both jaws.
Union of pelvic fins posterior to anus.	About two-thirds united.	Basal one-fourth to one-half united.	Basal one-half to two-thirds united.	No union-----	Only trace of union.
Enlarged dorsal denticles.	Present in embryos; and scars in very young.	A few remain in some adults.	Few scars on very young.	Not found on material available.	Not found.
Claspers-----	Short; hooks weak or absent.	Not examined-----	Long; hooks present-----	Long; no hooks-----	Short; no hooks.
Clasper siphons-----	Moderately short.	Not examined-----	Moderately long-----	Long-----	Short.
Egg retention-----	Oviparous as far as known.	Oviparous as far as known.	Both oviparous and ovoviviparous species.	Oviparous as far as known (in 1 species).	Oviparous as far as known (in 2 species).
Sexual dimorphism in tooth shape.	Not found-----	Said to be present to slight degree.	Not found-----	Not found-----	Strong tooth dimorphism in 1 species, not in 3 others.
Pores on snout-----	Not prominent.	Not prominent-----	Prominent-----	Not prominent-----	Very prominent.
Liver size in adults.	Large; posterior tips usually reach as far back as anal opening.	Not examined-----	Moderate; posterior tips of liver lobes not reaching as far back as anus.	Short; small; not extending appreciably into posterior half of body cavity.	Large; very long; tips reaching posterior to anus.

which there are no appreciable differences in the shape of the nasal flap or its nearness to the mouth.

Thus throughout the genus *Scyliorhinus*, excepting only *S. canicula* where the nasal flaps do provide a structural feature differing from that found in all other species, the best and by far the most reliable character for identification of specimens is their color pattern. Differences in proportions do exist, and there are other differences in denticle and tooth structure and in the shape and position of fins; but these differences seem to be of little practical usefulness at this stage of the study of the family except in the analysis of series of specimens and in preliminary determinations of probable relationships.

KEY TO WESTERN ATLANTIC *SCYLIORHINUS*

Note.—Preservatives dissolve oil from shark livers, adding yellowish pigments to specimens, sometimes turning gray colored specimens to brown.

- 1a. Dorsal surfaces (except fins) with randomly arranged but almost uniformly spaced, light-colored and nearly round spots in a brown background (brown in life as well as in preservative); darker areas representing seven saddles may be present but are usually obscure; lighter below, without spots.

S. torrei; Florida Straits, off northern coast of Cuba.

- 1b. Dorsal surfaces neither brown in life (but may be brown in preservative) nor covered by randomly arranged white spots; all species with variations on a basic pattern of seven saddles, a prepectoral, a pectoral, postpectoral, first dorsal, second dorsal, precaudal, and caudal saddles; additional darker areas (blotches or saddles) may occasionally appear in intermediate positions such as between the dorsal fins, but such blotches or saddles are usually more obscure than the seven principal saddles; lateral pattern, when present, sometimes with a series of blotches roughly alternating with saddles.

- 2a. Saddles made up of simple blotches of darker color, usually without included darker lines or darker spots; lighter areas within saddles sometimes present but rather indistinct, not appearing as round whitish spots smaller than diameter of eye; intermediate saddles and spots outside basic pattern few or absent.

S. meadi new species; Florida Straits, St. Augustine to Santaren Channel.

- 2b. Saddles and lateral blotches with nearly round, white or light-colored spots included within their margins, these spots usually smaller than diameter of eye; no dark lines or dark spots within the saddles; some specimens with reduced number of saddles.

S. hesperius new species; western Caribbean, off Honduras, Nicaragua, and Jamaica.

- 2c. Dorsal saddles with black marginal lines enclosing areas of the lighter background color, the enclosed areas usually not round, in most specimens the lines forming a reticulate pattern; the reticulate pattern commonly extended to form intermediate patterns obscuring basic pattern of saddles, but in a few specimens reduced and showing only as saddles with marginal lines but without reticulating lines (fig. 2A and 2B show patterns near extremes of variation in material examined); no round white spots and isolated black spots few.

S. retifer (Garman); southwestern edge of Georges Bank (New England) along the outer continental shelf and the continental slope to the Carolinas and along the continental slope southward; off both east and west coasts of Florida; along the continental slope in the Gulf of Mexico and the western side of the Yucatan Channel; present on western Caribbean Banks including Pedro Bank as far south as Latitude 13°30' N. Not yet reported from Cuba or the Antillean side of the Straits of Florida.

- 2d. Pattern of saddles usually outlined by small rounded black spots which may be present also outside the pattern; in some specimens black spots are so numerous as to obscure saddles; no white spots.

S. boa (Goode and Bean); Lesser Antilles and continental slopes of South America from Venezuela to northern Argentina.

Scyliorhinus torrei Howell-Rivero, 1936

Figures 4, 7, 14, and 27; tables 1, 3, and 4.

Scyliorhinus torrei Howell-Rivero, Proc. Boston Soc. Natur. Hist. 41(4): 43-44, pl. 9, 1936 (type locality off Havana in deep water).

S. torrei is the smallest species of the genus, the males becoming mature at about 250 mm. In this connection it should be noted that Ford (1921) finds no marked difference in sizes attained by males and females in *Scyliorhinus canicula* and that the series of all scyliorhinids examined in this study show no indication that there is a disparity in size attained by the sexes. The numbers of adult specimens examined, however, are too few to show this conclusively for any western Atlantic species. The largest specimen of *S. torrei* recorded is 209 mm. (Bigelow and Schroeder 1948). As might be expected from its small size and slender form, *S. torrei* has a short liver occupying only a part of the anterior half of the body cavity. Proportionally large ovarian eggs (in the right ovary in adult females) with diameters up to 10 mm. crowd other organs. In gross appearance the nidamental gland and oviducts in *S. torrei* are

much the same as in other western Atlantic scyliorhinids, but it is not known whether *S. torrei* is oviparous or ovoviviparous.

Howell-Rivero (1936) in describing *S. torrei* noted the presence of a nictitating membrane and by this (among other characters) distinguished it from *S. torazame* of Japanese waters. Among specimens of both species examined for this study there is some difference in the degree of development of the subocular fold. Gilbert and Oren (1964) have called attention to inconsistencies in use of the terms subocular fold and nictitating membrane or nictitans, and I follow their recommendation in restricting the meaning of subocular fold to indicate a poorly developed lower eyelid. The presence of a nictitans or its state of development has sometimes been assumed from the presence of a subocular fold or its length relative to the length of the eye. Although there are differences in the extent of development of the subocular fold in different species, there is also much variation within species apparent in museum specimens, some of it due to differences in methods of preservation. Winking by the nictitans was observed in the two European *Scyliorhinus* Gilbert (1963), but its functional movement has not been observed and reported for other scyliorhinids.

In males the extent of union of pelvic fins along their inner edges is variable in the material examined. In one immature male the inner edges are united throughout, and one adult male has fins that are not united at all. Other males examined have fins united along two-thirds to three-fourths of their inner margins. Bigelow and Schroeder (1948) state that male *S. torrei* have claspers extending far beyond the tips of the pelvics. The illustration (1948, fig. 35), however, shows that the claspers of their largest specimen reach only a short distance beyond the pelvic tips. In the material at hand, the fully calcified claspers of one adult male (the largest) fail to reach the tips of the pelvics. In two others the claspers extend a very short distance beyond the tips of the pelvics. The ventral (outer) surfaces of the claspers, in the unflexed condition, are covered with denticles except for the extreme tip. Denticle points are directed anteriorly (toward the clasper base) as in other sharks of the suborder Galeoidea. The inner surface does not have either denticles or hooks in the position indicated by Schmidt (1930) for hooks on claspers of *Scyliorhinus torazame* (Tanaka). On the adult male *S. torrei* at hand, there are somewhat irregular series of slightly enlarged denticles having sharp points directed ante-

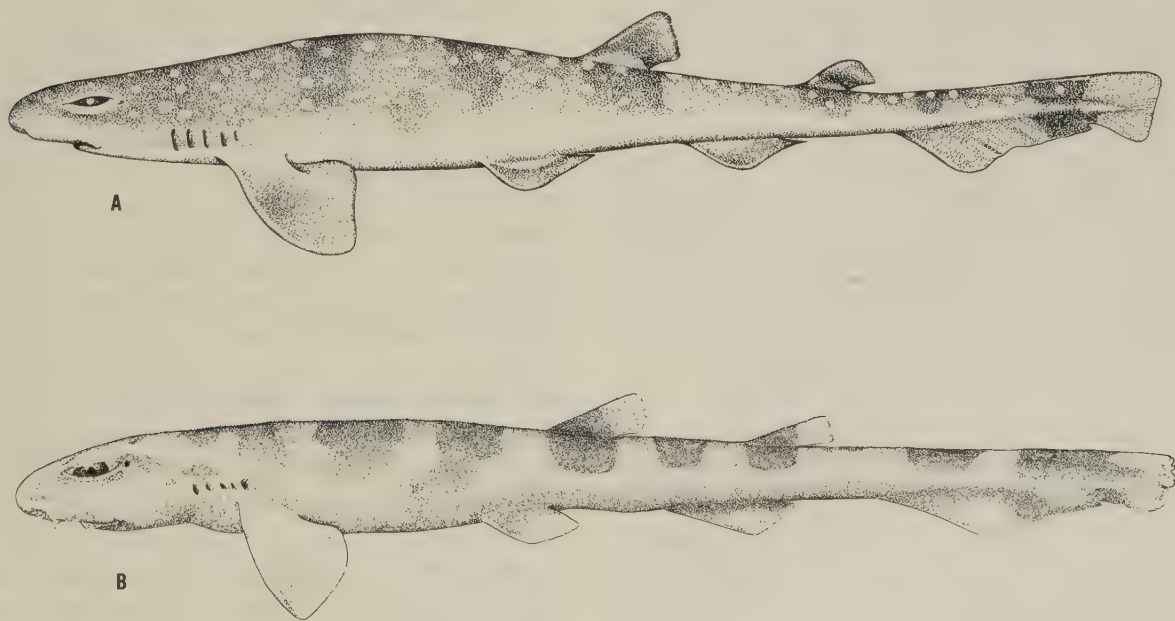


FIGURE 14.—A, *Scyliorhinus torrei* Howell-Rivero, drawn from a 258-mm. adult female collected at M/V Silver Bay station 2457; B, *Scyliorhinus meadi* new species, drawn from a 190-mm. young male taken at M/V Combat station 51.

riorly (toward the base of the clasper), but these denticles are on the side of the rhipidion adjacent to the main axis of the shark and in quite a different position than the hooks of the claspers of *S. torazame*.

The claspers of *S. torrei* are quite small and simple structures as compared with the claspers of *Galeus area*. The claspers of an adult male *Galeus arae* 275 mm. long are obviously more than 10 times the weight or volume of the claspers of an adult male *Scyliorhinus torrei* 272 mm. long and are considerably more complicated.

The stomach on one *S. torrei* contained cephalopod remains (beaks) including a cartilaginous eye capsule (*Sepia*?) 12 mm. in minimum diameter. Also present were several fish scales 4 to 7 mm. in breadth.

In addition to specimens for which measurements are summarized in table 4 (M/V *Silver Bay* stations 2457 and 3474 in Santaren Channel), specimens have been seen from M/V *Silver Bay* stations 2475 and 2477 in Santaren Channel; from M/V *Oregon* stations 1340 and 1343, also in the Santaren Channel; from M/V *Oregon* stations 2482, 3474, and 3512, northward from the Santaren Channel to the offing of Jupiter, Florida; and from M/V *Oregon* station 2650, near the Virgin Islands. Previously recorded specimens were from the north coast of Cuba (Bigelow and Schroeder, 1948). All recorded captures were from 366 to 550 m. except the one near the Virgin Islands which was in 229 m.

The teeth in the specimens at hand are in 21+21/20+2+20 to 23+23/21+1+21 rows. The tooth shape is similar to that of other Atlantic species of *Scyliorhinus*. In the specimens examined, the cusps of the extreme lateral teeth of the lower jaw are variably reduced, in some almost absent.

Scyliorhinus meadi new species

Figures 3, 7, 14, and 27; tables 1, 3, and 4.

Holotype.—An immature male, USNM 188049, 247 mm. in total length, taken at M/V *Silver Bay* station 3711, lat. 28°21' N., long. 78°51' W., at 329-m. depth off Cape Kennedy, Fla., January 26, 1962.

Additional material examined.—The species is known only from the holotype, an immature male and two immature females from the same station as the holotype, an immature male from M/V *Silver Bay* station 2475 from 549-m. depth in Santaren Channel, and an immature male from M/V *Combat* station 51, off St. Augustine, Fla. in 329-m. depth.

Diagnosis.—*S. meadi* differs from other species of the genus *Scyliorhinus* in color pattern. The upper parts are light gray in fresh specimens (brownish in specimens preserved in alcohol) with seven quite distinct darker rectangular blotches or saddles extending across the middorsal area, the first anterior to the pectorals, the second and largest (in specimens of the type series) at the level of the pectoral tips, the third anterior to the pelvic origin, the fourth through the first dorsal fin, the fifth through the second dorsal fin, the sixth at the base of the caudal fin, and the seventh across the caudal fin, anterior to the notch. In addition to the dorsal saddles, a series of lateral blotches of color alternate in more or less checkerboard fashion with the first three or four dorsal saddles, some of these extending indistinctly to the upper surfaces of the pectoral and pelvic fins. Traces of additional dorsal blotches are present between some of the principal dorsal saddles in some of the specimens. Lighter colored areas are included in some of the blotches, but these are indistinct and larger than the eye.

Two species of *Scyliorhinus*, *torrei* and *retifer*, are present in the same geographical area as *meadi*, but the color patterns of these are so strikingly different from that of *meadi* that there should not be any possibility for confusing them. No intergrades have been observed.

S. meadi appears to be closest in appearance to *S. hesperius* which is described in the following pages. Differences in color pattern between the two are constant in the material examined.

S. meadi also differs from other American members of *Scyliorhinus* in having the typical dermal denticles of dorsolateral surfaces somewhat larger in comparison with specimens of equal size, somewhat more erect, somewhat narrower, and somewhat more widely spaced. These differences are all a matter of degree and are not necessarily apparent unless specimens of similar size are compared. The differences do, in combination, give *S. meadi* a more shaggy appearance than any of the other American representatives of the genus.

Description of holotype.—An immature male, 247 mm. in total length and having dimensions as given in table 3. Body robust, caudal axis little elevated; head broad; snout broadly rounded, short; nasal flaps rather large, separated from one

another in the midline, nearly reaching mouth, no groove connecting nasal apertures with mouth; mouth broad, strongly arched; well-developed labial folds along the inner sides of the jaws extending about one-fourth the distance toward the symphysis, no labial folds along outer margins of jaws; orbital opening elongate, slitlike, a well-developed fold below the eye, not touching eyeball; spiracle small, its diameter less than one-fifth length of eye, located slightly below level of eye and at a distance about one-third the eye's longitudinal diameter from corner of eye; third gill slit above origin of pectoral, fourth, and fifth gill slits over pectoral; first dorsal fin slightly larger than second, its origin over the posterior half of base of pelvics and slightly nearer tip of snout than tip of caudal fin; pelvic fins united along their inner margins for about half the distance from cloaca to fin tips; pectorals broad, their free corners rounded, distal margins nearly straight.

Bases of typical denticles of dorsolateral surfaces separated from one another by distances one to four times the diameter of their bases; denticles three pointed, the central point long and heavy, lateral points weak and quite small with a strong central ridge, most denticles nearly erect, much longer than wide, their points directed upward and posteriorly; belly denticles similar; a few denticles of the edges of fins flattened, leaf-like, and without lateral points.

Teeth similar in the upper and lower jaws, three-cusped with an additional pair of lateral denticles on some teeth; the central cusp of teeth of the midportion of the upper jaw about twice as high as lateral cusps; teeth toward the angles of both jaws and in the lower jaw with somewhat lower central cusps; about three series of teeth functional, in about 25+0+25/25+0+25 rows.

Color pattern as described in preceding key and diagnosis.

Notes.—*S. meadi* specimens were collected within the general geographical range of *S. retifer* and adjacent to the areas in which *S. torrei* have been found. It is possible that all three species occupy different habitats. Species of *Scyliorhinus* taken by exploratory fishing vessels off the southeastern States and in the Caribbean have been, with one exception, collected from depths between 180 and 914 m. Along much of the Atlantic coast this is a relatively narrow strip (fig. 1). In the Florida

Straits region, a wider band of sea-bottom falls within this depth range and supports a remarkably diverse fauna of sharks and rays. Collections in the area in general suggest that many of these have quite restricted distributions, possibly due to narrow habitat preferences.

S. meadi is named for Giles W. Mead, who first called my attention to a specimen of the species.

Scyliorhinus boa Goode and Bean, 1896

Figures 15 and 27; tables 1, 3, and 4

Scyliorhinus boa Goode and Bean, Spec. Bull. U.S. Nat. Mus., p. 17, 1896 (type locality, Blake station 291, off Barbados).

Catalus haeckelii Miranda-Ribeiro, Mem. Mus. Nac. Rio de Janeiro, 14:163, pl. 8, 1907.

Scyliorhinus fernandezi Weihezahn, Novedades Cient. Mus. Hist. Nat. La Salle, Caracas, Ser. Zool. No. 9: 3-7, 1953.

Goode and Bean (1896, p. 17) did not intend to describe the species but did, in fact, satisfy the requirements of a valid description by publishing a name and a diagnosis based on the single 6-inch specimen collected off Barbados which is the type (Harv. Mus. Comp. Zool., 1835). They note a general correspondence in color with *S. retifer* and state that in approximately the track of the narrow lines observable in Garman's specimen (*S. retifer*) may be found various spots and blotches of blackish-brown. The similarity to a basic color pattern in each of the Atlantic American species has been mentioned. In the 14 specimens of *S. boa* examined and reported in table 3 and a few other specimens that have been examined, the color pattern is consistent in the absence either of the reticulating black lines or of continuous unbroken black lines around saddles that characterize specimens of *S. retifer* at all ages. Also none of the specimens of *S. boa* examined have white spots in the saddles as do all of the specimens of *S. hesperius* examined.

The pattern of spots in *S. boa*, however, does vary considerably. The dorsal saddles or their outlines are obscure in one specimen, and small black spots are quite numerous and randomly distributed over the dorsal and lateral surfaces. In most of the specimens the saddles and lateral blotches are outlined by discrete black spots, more or less round and much smaller than the eye. The spots extend on to the upper surfaces of the pectoral and pelvic and are present on the dorsal

fins and on both the upper and lower lobes of the caudal fin.

Species described as *Catulus haeckelii* Miranda-Ribeiro, 1907, and as *Scyliorhinus fernandezi* Weibezahn, 1953, are regarded here as being synonymous with *S. boa*. The geographical range of *S. boa* extends at least from the continental slope of central Venezuela eastward and southward to Rio de Janeiro where it was taken by Miranda-Ribeiro (1907). Dr. Elvira M. Siccardi has told me (personal communication) of the presence of *S. boa* or a closely allied population off the northerly coast of Argentina. A photograph of one specimen shows somewhat longer and larger black spots than characterize the specimens seen from Venezuela and the Guianas. Whether the juvenile specimen reported by Bigelow and Schroeder (1948) from the north coast of Cuba is correctly identified as *S. boa* now appears questionable. Material examined in this study in addition to the type is from 10 stations of the M/V *Oregon* off the coasts of Venezuela, the Guianas, and Brazil, from lat. 11°34' N., long. 62°52' W., to lat. 01°52' N., long. 46°54' W., in 293 to 402 m.

The teeth in *S. boa* in specimens examined were from 24+24/21+1+21 to 25+25/23+1+23. The teeth were somewhat smaller than the teeth of other western Atlantic *Scyliorhinus* of similar size. Also the central cusps are comparatively shorter, and nearly all teeth have five cusps, with only teeth of the central part of the upper jaw having the middle cusp of each tooth twice as long as the cusps next to it.

The dermal denticles of the dorsolateral surfaces differ from the denticles of *S. meadi* in being smaller, wider (some of them nearly as wide as long), set closer together, and less erect. The denticles of *S. boa* differ very little from denticles of other Atlantic American members of the genus. Denticle differences due to age and perhaps also to intraspecific variation are so great, however, that these are probably not ordinarily useful in identifying material.

S. boa seems to be a smaller species than *S. retifer* or *S. hesperius*, since a 346-mm. male is sexually mature. The claspers of this male reach 4 mm. past the tips of the pelvics which are united to one another along their inner margins to within 6 mm. of their tips. The claspers are not provided with hooks but have a few slightly enlarged den-

ticles which have points directed anteriorly (toward the base of the claspers) as in the denticle arrangement on claspers of all galeoid sharks.

Scyliorhinus retifer (Garman), 1881

Figures 2, 5, 6, 7, 8, and 27; tables 1, 3, and 4

Scyllium retiferum Garman, Bull. Mus. Comp. Zool. 8:233, 1881 (type locality, lat. 38°23' N., long 73°34' W.).

This species is easily recognized by its unique pattern of reticulating lines sometimes reduced to black edging lines along margins of saddles and blotches. It is the only Atlantic American catshark known well enough to have acquired an English common name, the chain dogfish. It is frequently taken by trawlers operating off the Virginia Capes.

The known range of the species extends from the offing of southern New England and the southwestern edge of Georges Bank to Nicaragua. Bigelow, Schroeder, and Springer (1953) note that it has been taken at depths of 73 to 229 m. in the northern part of its range. Specimens of *S. retifer* have been seen from more than 100 stations of Bureau of Commercial Fisheries Exploratory Fishing vessels between the Virginia Capes, the lower Gulf of Campeche, and off central Nicaragua (lat. 13°30' N., long. 82°00' W.), along the continental slope. The station with the least depth was at 165 m. off Cape Henry, Va., where over 500 juveniles about 160 to 200 mm. long were taken in early May, 1961. Southward the collections were at greater depths, for the most part from 330 to 450 m. off Florida and in the Gulf of Mexico, but 500 to 550 m. off Nicaragua. One specimen of *S. retifer* was taken from M/V *Oregon* station 1883 on the continental slope off Honduras at 365 m. where a specimen of *S. hesperius* was also taken. Southward from this station along the continental slope for a distance of about 200 miles, where the two forms occupy adjacent or nearly overlapping ranges, *S. retifer* was taken in an average depth of 525 m. (460 to 550 m.) at 16 stations, while *S. hesperius* was taken at an average depth of 400 m. (274 to 530 m.) at 7 stations.

A peculiarity of the distribution of *S. retifer* is that records of its occurrence on the Antillean side of the Straits of Florida (off Cuba and the Bahama Banks) are absent. *S. torrei* records are chiefly from this area, and one of the three sta-



FIGURE 15.—A, *Scyliorhinus boa* (Goode and Bean) drawn from a 348-mm. female from M/V *Oregon* station 2351; B, *Scyliorhinus hesperius* new species, drawn from a 260-mm. female from M/V *Oregon* station 1883.

tions where *S. meadi* was taken is close to the Bahama Banks.

Despite the extensive collection of *S. retifer* available for study, few of the specimens are adults. A male, 395 mm. in total length, taken by the Bureau of Commercial Fisheries M/V *Delaware* in 128 m. off Delaware Bay, was the only specimen observed that was determined to be sexually mature.

A 475-mm. female taken from 402 m. off Pensacola, Fla., was the largest specimen examined. The ovary was extremely small, without evidence of developing eggs.

The stomach of the 475-mm. specimen contained 12 cephalopod beaks of more than one type.

Teeth of specimens of *S. retifer* are in 21+21/19+2+19 to 26+26/21+4+21 in specimens examined. In form, the teeth of *retifer* do not differ greatly or consistently from teeth of other Atlantic American species of *Scyliorhinus*.

Scyliorhinus hesperius new species

Figures 7, 9, 15, and 27; tables 1, 3, and 4.

Holotype.—An immature female, USNM 187732, 415 mm. in total length, taken at M/V *Oregon* station 3598, lat.

09°03' N., long. 81°22' W., at 360- to 400-m. depth on the Caribbean coast of western Panama, May 31, 1962.

Additional material examined. Twelve specimens, 177 to 466 mm. total length, taken at M/V *Oregon* stations 1870, 1883, 3522, 3565, 3574, 3575, 3598, 3599, 3626, 4480, and 4482, all in the western Caribbean from the vicinity of Jamaica and Honduras, southward to Panama and off Baranquilla, Columbia, in 274- to 530-m. depth.

Diagnosis.—*S. hesperius* resembles *S. boa*, *S. meadi*, and *S. retifer* in proportions and external structural features but differs from these species in having from 2 to about 35 round white spots, smaller than the diameter of the eye, within each of the dorsal saddles and lateral blotches. The species differs from *S. retifer* in the absence of reticulating lines or in the absence of darker margins around the saddles and blotches. It differs from *S. boa* in the absence of small black markings either scattered or outlining the saddles and blotches. The presence of small white spots in *S. hesperius* separates it from *S. meadi* in all the specimens seen. The white spots in *S. hesperius* are concentrated in the saddles and blotches and are not more or less randomly distributed as in *S. torrei*.

Description of holotype.—An immature female, 415 mm. in total length and having dimensions as

given in table 3. Body robust, caudal axis not elevated; head broad; snout broadly rounded, short; nasal flaps rather large, each with a central swelling dividing each flap into two portions which cover the two parts of each nasal aperture, separated from one another in the midline, nearly reaching mouth, no groove connecting nasal apertures with mouth; mouth broad, moderately arched; well-developed labial folds extending a short distance along the inner sides of lower jaws, no labial folds along outer margin of upper jaws; orbital opening elongate, slitlike, a well-developed fold below eye, not touching eyeball; spiracle small, located short distance from rear corner of eye, about same level as eye; fourth and fifth gill slits over pectoral base; first dorsal origin over end of base of pelvis, its area about twice that of second dorsal; second dorsal origin slightly in advance of posterior end of anal fin base; anal fin origin very slightly posterior to free tip of first dorsal, its free tip reaching end of base of second dorsal; caudal fin less than one-fourth total length; pectoral fins broad, short, their distal margins nearly straight; pelvic fins united along their inner margins about half the distance from anus to fin tips.

Denticles, three-ridged, imbricate, with a single strong apical (posterior) point with a weak lateral point on each side, denticle size not uniform, some twice as large as others.

Teeth similar in upper and lower jaws, small, in 24+0+24/22+2+22 rows; each tooth with 3 or more smooth-edged cusps, the central cusp longest, most teeth with two pairs of lateral cusps, the outer pair very small.

Color pattern of type approximately as illustrated for specimen shown in figure 15B.

Schroederichthys new genus

Type species—*Schroederichthys maculatus* n. sp.

Members of this genus differ from nearly all other sharks in having the postpelvic trunk region in advance of the caudal fin greatly elongated, the distance from the origin of the pelvis to the origin of the caudal fin lobes about one and three-fourths times the distance from the tip of the snout to the origin of the pelvis. In this character of body proportions, members of the genus *Schroederichthys* show a parallel development with some Australian sharks of the family Orectolobidae,

particularly *Hemiscyllium*. These orectolobids, however, have quite different arrangements of parts near the mouth and have nasoral grooves and barbellike structures. In *Schroederichthys* also the anal fin is separated from the lower caudal lobe by a considerable distance (a distance equal to about two times the length of the base of the anal), whereas in some orectolobids (*Hemiscyllium* and related genera) only a notch separates the anal from the lower caudal lobe.

Schroederichthys differs from *Scyliorhinus* in having definite though short labial grooves along both upper and lower jaws at the corners of the mouth. It is similar to the two Chilean-Patagonian species provisionally referred to the genus *Halaehururus* in having upper labial grooves or folds. *Schroederichthys* differs from these species in having a somewhat longer postpelvic trunk, shorter labial grooves, and consistently (at all ages in *S. maculatus*) multicusped teeth in both jaws.

Generic description.—Small slender sharks of the family Scyliorhinidae having greatly elongated caudal regions with relatively short caudal fins; distance from tip of snout to vent about half the distance from vent to tip of tail; caudal axis little elevated, lower caudal fin not produced as a lobe; two dorsal fins, second dorsal slightly larger than first and similar in shape, first originating behind posterior end of pelvic base; anal fin relatively low, its base longer than base of either dorsal fin; pectoral fins relatively broad, their distal margins straight or very slightly convex, their outer corners rounded; pelvic fins with their inner-posterior corners somewhat produced and their distal margins oblique, pelvis of males united at bases for a very short distance, not forming an apron.

Snout only moderately rounded; nasal flaps small but extending across the nasal apertures; nostrils not united with mouth by a groove and separated from mouth by a distance as great as or greater than width of nasal flap; mouth strongly arched; labial grooves short but extending around corners of mouth; eye elongate, with well-marked fold below, not in contact with eye; spiracle small, on level of eye and close behind it; gill slits five, anterior longest, two posterior slits over pectoral base; no ridges or keels in skin, no precaudal pits, a shallow groove on midventral line posterior to

pelvis and extending, interrupted by anal fin, nearly to lower caudal fin.

Teeth similar in upper and lower jaws (fig. 9), principal ones with three or five cusps, central cusp of each tooth much the longest, three to five series functional. Dorsolateral denticles (fig. 7F) for the most part imbricate, three pointed, the central posteriorly directed point much the longest, ventral denticles leaf-shaped, with a single point.

Vertebrae (in 36 specimens) 132 to 142, monospondylous vertebrae 29 to 35.

Type species oviparous, eggshells (fig. 19) with rather thick walls, their surfaces striated longitudinally, opaque, about 44 mm. by 14 mm., not including tendrils developed at the four corners.

Claspers of adult males of type species long, extending well beyond tips of pelvis, their tips tapered, without hooks; clasper siphons very large, long, extending under skin of belly as far forward as axils of pectorals.

Livers relatively small, occupying only the anterior half of body cavity in adults.

General pattern of seven dorsal saddles of darker color showing at least in young; sometimes obscure in adults in the type species.

The genus is named for William C. Schroeder, whose careful and pioneering work with Henry B. Bigelow on cartilaginous fishes contributed

greatly to a renewal of interest in problems relating to this important group of marine animals.

Schroederichthys maculatus new species

Figures 4, 5, 7, 9, 16, 17, and 19; tables 1, 5, and 6.

Holotype.—Adult male 328 mm. total length, USNM 185556, collected in shrimp trawl at R/V *Oregon* station 1870, August 21, 1957, from about 410 m.; lat. 16°39' N., long. 82°29' W., in the Caribbean sea NNW of Cape Gracias a Dios, Honduras.

Paratype.—An adult female 335 mm. in total length, taken in the same haul with the holotype.

Diagnosis.—*Schroederichthys maculatus* is readily distinguished from sharks of all other genera by the proportionately greater length of the tail region. It differs from the other species of *Schroederichthys* described in this paper in color, in the shape of the nasal flap, which in *S. maculatus* is triangular with a somewhat bilobed distal margin as compared to the narrower, longer flap with a simple rounded tip of the other species. The color differences are so great between the two species of *Schroederichthys* that other differences are of comparatively little interest for practical identification of the two forms. *S. maculatus* has a color pattern almost identical with that of *Scyliorhinus torrei* Howell-Rivero. The dorsal surfaces are tan or light brown with round, ovoid, or irregularly shaped white or cream-colored spots about 1 to 3 mm. in diameter scattered over the dorsal surfaces except on the surfaces of the dorsal

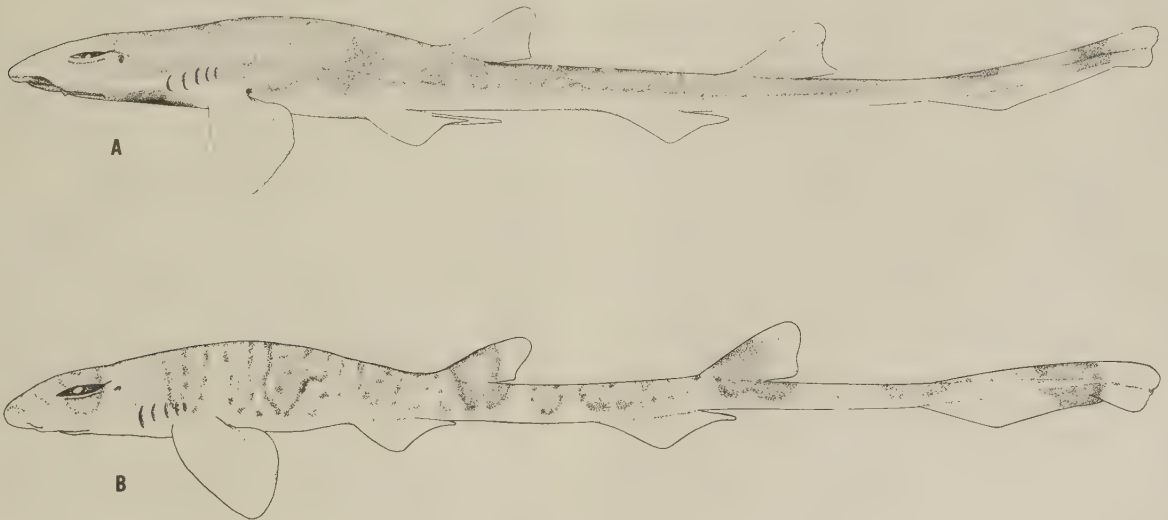


FIGURE 16.—A, *Schroederichthys maculatus* new species, drawn from the type, USNM 185556, a 328-mm. adult male; B, *Schroederichthys tenuis* new species, drawn from the type, USNM 188052, a 230-mm. immature male.

fins and the paired fins, and with traces of 10 dorsal saddles appearing as areas of somewhat intensified brown color; these saddles are obscure or absent anteriorly in some adults. This color pattern is so close to that of *Scyliorhinus torrei* that specimens in a mixed lot of the two species are not readily distinguishable from one another on the basis of color. The other species of *Schroederichthys* resembles *Scyliorhinus boa* in general coloration, having a pattern of dark spots and lines on a lighter background.

Description of the holotype.—The holotype is shown in figure 16A, and measurements are given in table 5. Teeth in $24+2+24/(18+)+2+(18+)$ rows; most of them tricuspid but some with additional small lateral cusps; largest upper jaw teeth about 0.9 mm. high by 0.7 mm. in greatest width, central cusp projecting beyond base about five times length of lateral cusps, edges of cusps smooth, six or more low surface ridges extending from bases about half-way toward tips of cusps; lower jaw teeth similar but central cusps somewhat lower, length of central cusp of largest tooth about four times height of lateral cusps, surface ridges very short, present only on lower portion of the bases.

Typical denticles of dorsolateral surfaces about 0.4 mm. long by about 0.2 mm. wide, with three points directed upward and posteriorly, central point much the longest, not very close set, with skin surface showing around each denticle but points overlapping, imbricate.

Color of dorsolateral surfaces of body light brown with numerous round or oval spots of lighter color, about half the length of the eye or smaller and irregularly scattered; darker brown dorsal saddles without definite darker edging present but obscure anteriorly and extending to fins only as a trace of darker color; no definite spots on fins; ventral surfaces white, unmarked.

Notes.—*Schroederichthys maculatus* is known from 48 specimens, all from the Caribbean continental slope of Central America off Honduras and Nicaragua. The specimens were collected from depths of 190 to 410 m., most of them near Rosalind Bank and Quita Sueño Bank. The capture of more than 30 specimens in one net haul suggests that the species is locally abundant.

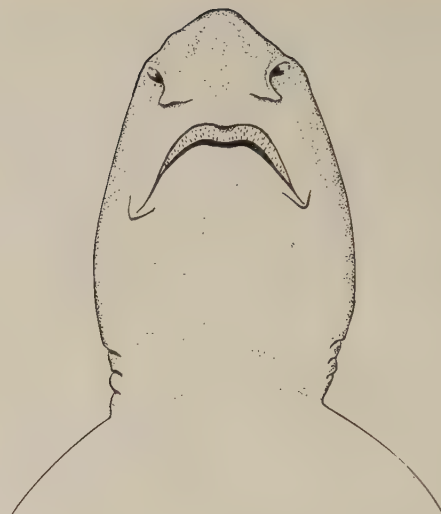


FIGURE 17.—*Schroederichthys maculatus* new species, ventral side of head of the type, USNM 185556.

Schroederichthys tenuis new species

Figures 16 and 18; tables 1, 5, and 6.

Holotype.—An immature male 230 mm. in total length, USNM 188052, collected in a shrimp trawl at M/V Oregon station 2083 on November 17, 1957, from about 410 m. at lat. $01^{\circ}49' N.$, long. $46^{\circ}48' W.$, in the Atlantic off the mouth of the Amazon River.

Paratype.—An immature male 180 mm. long, USNM 188053, taken in the same haul with the holotype.

Diagnosis.—*Schroederichthys tenuis* is known only from the types, both immature males. There appear to be no important differences in body proportions between these specimens and specimens of *S. maculatus* of comparable size. *S. tenuis* is, of course, readily separable from sharks of other genera. From *S. maculatus*, it differs greatly in color pattern. In addition, *S. tenuis* has a nasal flap longer than wide, and its tip is simply rounded, not pointed or bilobed. The typical dermal denticles of dorsal surfaces in *S. tenuis* are proportionally somewhat narrower than in *S. maculatus* and more erect. Some have three posteriorly directed points, but many of them lack lateral points and are needlelike, although usually showing a central ridge. The color pattern of *S. tenuis* is made up of dark spots on a lighter ground color, the spots assembled to form a series of dorsal saddles.

Description of holotype.—The holotype is shown in figure 16B and measurements are given

in table 5. Teeth in 22+22/16+2+16 rows, about half with three cusps and half with five cusps. Color of dorsolateral surfaces light brown without lighter colored spots or markings; pattern of seven dorsal saddles plus several more or less distinct intermediate saddles edged with broken lines of darker color, saddles at the first dorsal and second dorsal fins more intense and extending across the fins, caudal fin strongly marked, paired fins and anal fin only faintly marked.



FIGURE 18.—*Schroederichthys tenuis* new species, ventral side of head of the type, USNM 188052.

Notes.—The collection of only two specimens of this species nearly 2,000 miles from the area from which *S. maculatus* is known illustrates the incompleteness of the sampling of the fauna from continental slopes.

Genus *Galeus* Rafinesque, 1810

Type species—*Galeus melastomus* Rafinesque, designated by Fowler, 1908.

Galeus is a genus with about eight nominal species, one of which, *Galeus melastomus* Rafinesque, of the eastern North Atlantic region, is well known. Members of the genus are characterized by the presence of a spiny crest of enlarged denticles on the upper margin of the caudal fin (fig. 21) and a comparatively long snout. An Australian scyliorhinid with enlarged denticles forming crests along both the upper margin of the upper caudal lobe and the anterior margin of the lower caudal lobe has been split off from *Galeus*



FIGURE 19.—Partially formed egg case of *Schroederichthys maculatus* taken from an oviduct of a 342-mm. female collected at M/V *Oregon* station 1870, August 21, 1957. The egg case was 44 mm. long by 14 mm. in greatest width, and the posterior tendrils (broken off in drawing) were 225 mm. long. The anterior end of the egg case was still within the nidamental gland area when taken, and anterior tendrils had not formed. The egg case wall was rather thick, opaque, olive colored, and striated longitudinally.

under the name *Figaro boardmani* (Whitley). A group of two Pacific scyliorhinid species, *Parmaturus xaninurus* (Gilbert) and *P. pilosus* Garman, have crests with specialized denticles along the upper margin of the caudal fin, but these crests extend somewhat onto the lateral surface of the upper caudal lobe, and the marginal scales, although enlarged, do not project outward from the tail to the degree characteristic of these scales in *Galeus*. Also, these sharks, *Parmaturus*, have comparatively short snouts and broad heads, much different in general shape from members of the genus *Galeus*. One other cat shark, *Apristurus profundorum* (Goode and Bean), also has denticles on the upper margin of the dorsal fin differing in size and shape as well as in spacing from denticles on the lateral surfaces of the tail and most other parts of the body (see fig. 23). The crest is less well defined in *Parmaturus* than in *Galeus*, and in *Apristurus profundorum* there are no enlarged and projecting denticles marking the margin of a crest.

The presence of an upper caudal crest with

much enlarged marginal scales, the crest not extending appreciably onto the lateral surface of the tail, appears to be a unique feature of *Galeus* and sufficient for diagnosis in the present treatment of scyliorhinid genera. Other characters, such as the long and structurally specialized claspers, may also be useful in the definition of the genus; but until more Pacific and eastern Atlantic specimens have been examined, I wish to avoid tampering with generic definitions and will rely on characters clearly outlined in the literature.

Species of the genus as presently understood may be divided into two groups on the basis of color pattern. One group comprises plain colored species, sometimes with fin markings of contrasting color but without a pattern of cloudy spots or blotches generally distributed over dorsolateral surfaces. Plain colored species are *Galeus sauteri* (Jordan and Richardson) of the western Pacific and *Galeus jensenii* (Saemundsson) and *Galeus murinus* (Collett) of the northeastern Atlantic. Another western Pacific species, *Galeus hertwigi* (Engelhardt), said to have a short snout and a tail with contrasting color pattern, has been included in the genus *Galeus* by Fowler (1941).

The other group of the genus is characterized by the presence of a pattern of blotches or spots over the dorsolateral surfaces. This group includes *Galeus melastomus* Rafinesque of the eastern North Atlantic, *Galeus polli* Cadenat from the west coast of Africa, and the western Atlantic forms treated here. In addition, a Pacific species, *Galeus eastmani* (Jordan and Snyder, 1904), has been described as having "indistinct clouds of deeper shade." It appears from examination of the type (SU 7740) that these markings are less pronounced than in any of the western Atlantic forms. *Galeus eastmani* differs markedly from Atlantic species in being more slender, having a more sharply pointed snout, having a larger spiracle, and in having heavier denticles.

KEY TO ADULT SPECIMENS OF WESTERN ATLANTIC GALEUS

- 1A. Anal fin long, its origin under a vertical through the posterior tip of the first dorsal fin and its rear tip nearly reaching (to within one-half diameter of the eye) origin of lower caudal lobe... *Galeus cadenati* n. sp.
- 1B. Anal fin short, its origin in back of a vertical through the posterior tip of the first dorsal fin and its rear tip separated from the origin of the lower caudal

lobe by a distance equal to the horizontal diameter of the eye or more..... *Galeus arae* (Nichols)

Galeus arae (Nichols), 1927

Figures 4, 5, 7, 20, 21, and 27; tables 1, 5, and 6.

Galeus arae is a much smaller species than *G. melastomus* of the eastern North Atlantic and Mediterranean. None of the *G. arae* seen exceed 37 cm. while *G. melastomus* reaches a length of over 90 cm. *G. melastomus* lays eggs in leathery cases similar in general appearance to egg cases of other scyliorhinids. Although adult female *G. arae* with large ovarian eggs have been collected, none have been observed with eggs or embryos in the oviducts and no egg cases have been collected that can be referred with confidence to western Atlantic *Galeus*.

Galeus arae is very commonly taken in shrimp trawls off the coast of Florida, both in the Atlantic and the Gulf of Mexico. Examples have been recorded for more than 100 stations of exploratory fishing vessels, usually with several specimens from each station. Collections from single hauls indicate strong tendencies to segregation by size and sex, but no well-defined pattern in the depth of occurrence of immature or of adult males or females has appeared.

The records at hand show *Galeus arae* to be locally common from about 330- to 460-m. depth around Florida, from the offings of Jacksonville to Pensacola, and usually at greater depths, 400 to 620 m., in the Yucatan Channel, near Pedro Bank and Jamaica, and around some of the banks and islands of the Caribbean off the coasts of Nicaragua and Costa Rica southward to lat. 13°30' N. Three atypical specimens from the vicinity of Puerto Rico, provisionally referred to *G. arae*, are from 293- and 402-m. depth. The Puerto Rican specimens are more robust than the typical *G. arae* and have a poorly defined pattern of spots (fig. 20C). They may represent an undescribed species, but closely resemble *G. arae* in morphology and proportions. Larger series are needed to assess the status of the Puerto Rican specimens.

Bigelow and Schroeder (1948), referring to a series of specimens taken off Tortugas and off the north coast of Cuba, note that one specimen of about 295 mm. has claspers falling short of the tip of the pelvics, while in another male of 317 mm., the claspers extend far beyond the tips of the

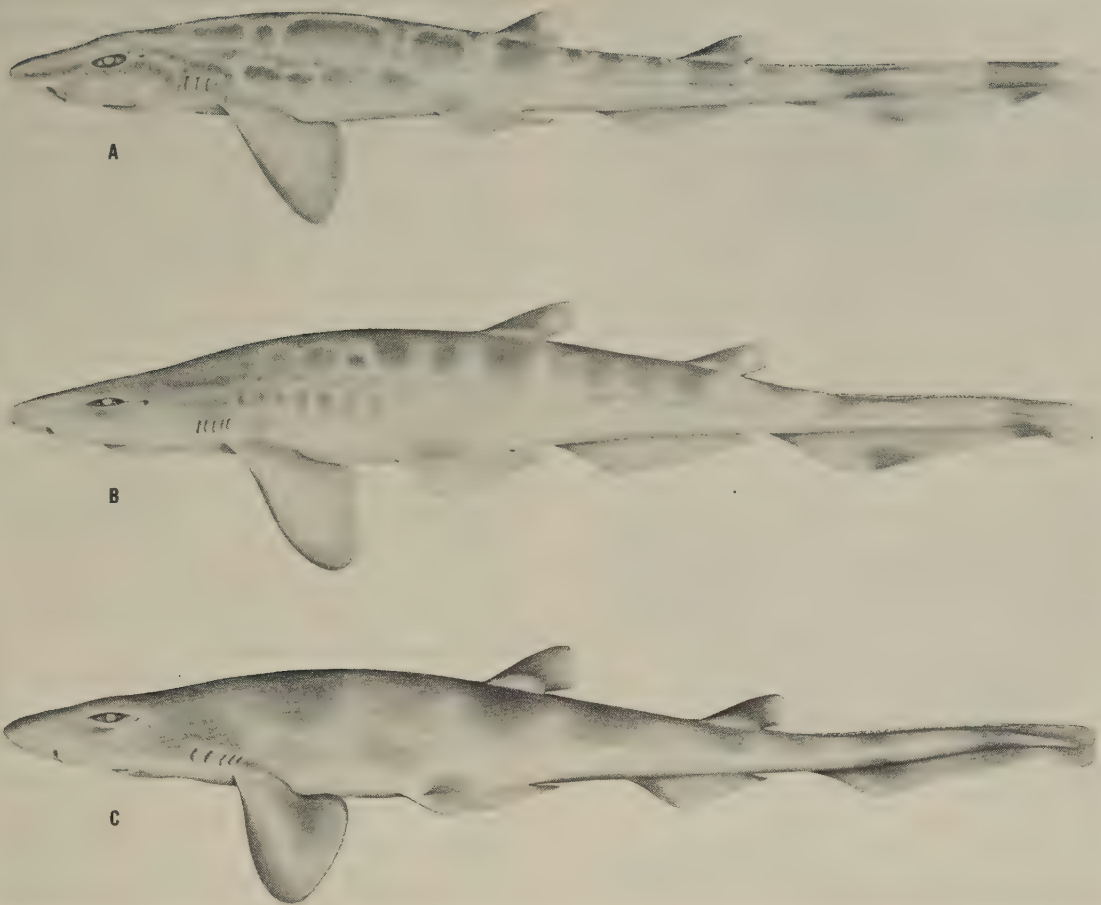


FIGURE 20.—A, *Galeus arae* (Nichols), drawn from a 290-mm. female; B, *Galeus cadenati* new species, drawn from a 300-mm. female; C, *Galeus arae*, drawn from a 320-mm. female from Puerto Rico, showing color pattern found on large examples from that area.

pelvics. From this they conclude that maturity is probably attained at about 300 mm. The extensive series of *G. arae* that I have examined includes large numbers of adult males from the Florida and Central American slope. These are 265- to 290-mm. specimens for the most part, and no examples of either sex exceed 330 mm. The specimens from Puerto Rico already mentioned include two adults, a 368-mm. male, and a 352-mm. female. They are not only appreciably larger than any observed from the continental slope but also differ in some body and fin proportions. As shown in table 6, the Puerto Rican specimens have a proportionally shorter anal fin and differ in other measurements from Florida examples of *G. arae*.

Galeus cadenati new species

Figures 20, 21, and 27; tables 1, 5, and 6.

Holotype.—A female 303 mm. in total length, USNM 260468, F1 collected at R/V *Oregon* station 3592, lat. 09°13' N., long. 80°44' W., in 439-m. depth off the Caribbean coast of Panama, May 30, 1962.

Diagnosis.—A small species of the genus *Galeus* differing from *G. arae* in having a comparatively longer anal fin (13.2 to 15.0 percent of total length compared to 8.7 to 13.6 percent in *G. arae*) with the tip of the anal reaching nearly to the lower caudal origin, separated from it only by a distance less than half the horizontal diameter of the eye as compared to separation by a distance equal to the horizontal diameter of the eye or more in *G. arae*. The pectoral fins and the two dorsal fins of

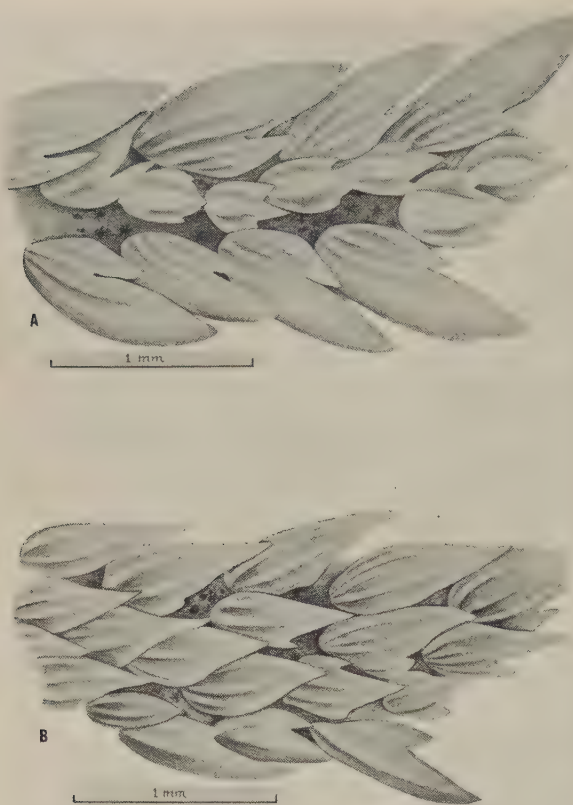


FIGURE 21.—Enlarged scales of caudal crests drawn from sections near the origin of upper caudal lobes of: A, *Galeus arae*; and B, *Galeus cadenati*.

G. cadenati are proportionally somewhat longer than the fins of *G. arae* (table 6). Minor differences in the caudal crest are shown in figure 21, the crest in *G. cadenati* being about three-fourths the width of the crests in *G. arae* of comparable size.

This species is similar to *Galeus polli* Cadenat, 1959, which is found abundantly on the west coast of Africa. I have compared specimens of the new species with a large series of *G. polli*, including examples from several localities, collected by vessels of the Guinean Trawling Survey and loaned to me through the Smithsonian Institution Sorting Center. Both *G. polli* and *G. cadenati* have long anal fins and are readily separable from *G. arae* on this basis. *G. polli* has a longer snout (as measured from the front of the mouth) and a narrower head than *G. cadenati*, but proportional differences in snout length and distance between the nostrils are not great in all specimens at hand. In Cadenat's table (1959) of proportions for four

large adult *G. polli*, distances from the top of the snout to the front of the mouth are shown as 7.4 to 8.5 percent of total length as compared to 6.0 to 7.3 percent in our specimens of *G. cadenati*.

Differences between *G. polli* and *G. cadenati* that are not especially notable in comparison of measurements are easily seen in side by side comparison of the two species. *G. cadenati* has a more robust form, a wider and shorter head, and a wider and shorter mouth. The color differences in the specimens examined are also striking. The specimens of *G. cadenati* are brown with the spots and saddles of the posterior part of the trunk rather indistinct. All of the specimens of *G. polli* available for examination are grayish with black or nearly black spots and saddles. In most of the specimens the spots and saddles are more clearly defined; but a few specimens are dark all over, and the spots and saddles are indistinct.

Description of the holotype.—Measurements of the type, USNM 260468-F1, are given in table 5, and the color pattern in the type does not differ appreciably from that illustrated (fig. 20B) for the species. Body moderately slender, caudal axis not elevated, body sector (tip snout to anus) about two-fifths of total length; head broad, snout moderately pointed and not greatly flattened dorso-ventrally, with large, medially located, and elongate patches of mucous pores above and below, the pore openings small, arranged in irregular rows; nasal apertures large, about half the length of snout measured to front of mouth, oblique, with a triangular flap covering the posterior opening when closed, well separated from mouth; mouth large with labial grooves above and below, the lower longer, reaching about one-fourth the distance toward the symphysis; eye large, oval, length of orbit more than two times its width, no functional nictitating membrane, but a subocular fold; spiracle moderate, located immediately behind and slightly below level of horizontal axis of eye; gill openings short, longest about half the horizontal diameter of eye, the fourth and fifth located above the origin of the pectoral; pectoral long, about two times length of snout and broad, its greatest width about two-thirds the length of its anterior margin, its distal corners rounded; first dorsal fin origin nearly over middle of pelvic base, its distal margin only slightly convex, its apical and lower tips moderately rounded; second dorsal fin about

as large as first dorsal; dorsal fin bases separated by a distance about equal to length of anal base; second dorsal similar in shape to first dorsal, its origin posterior to middle of base of anal, its posterior tip separated from origin of caudal crest by a distance equal to one-half horizontal diameter of orbit; pelvic fins large and long, united and adnate to body for a short distance posterior to anus, their posterior tips pointed; anal fin long, its base $2\frac{1}{2}$ times base of first dorsal, its height about equal to height of second dorsal; upper caudal with crest of modified denticles (see fig. 21B), caudal fin slightly less than one-third total length; lower caudal fin about same height as anal, its margin rounded without forming a pointed lobe, a notch near the tip.

Denticles over dorsolateral surfaces small, three pointed, the central point much the longest, similar to denticles of *G. arae* (see fig. 7).

Teeth relatively small, multicusped, largest three or five cusped with central cusp much the longest, similar in shape in upper and lower jaws, several series functional; upper teeth in 31+31 rows; lower teeth in oblique series, not readily counted by row.

Notes.—*Galeus cadenati*, so far as known, is found only in the southwestern Caribbean off the coast of Panama. Although this is quite near the range of *Galeus arae*, which occurs off the coast of Nicaragua, the collections seen show no overlapping.

Eastward and along the Caribbean or Atlantic coasts of Columbia, Venezuela, the Guianas, and northern Brazil, specimens of *Galeus* have not been reported although collections from these areas have produced many small sharks of other genera in depths at which *Galeus* would be expected to occur.

Genus *Apristurus* Garman, 1913

Type species *Scylliorhinus indicus* Brauer, 1906, by original designation.

The genus *Apristurus* as understood here (*Pentanchus profundicollis* Smith and Radcliffe is excluded) contains about 16 species. Four western Atlantic species are recognized. Members of the genus are small sharks, for the most part less than a meter long, with broad and flattened heads which are sometimes described as shovel-shaped. All of the known species are rather uniform black or dark brown in life. Lighter colors on some

museum specimens (*Apristurus profundorum*) are thought to be due to handling accidents or to effects of preservatives.

Various sets of characters have been used in descriptions of species of *Apristurus*, but most authors have relied on morphometrics to define species. This has not been very satisfactory because some descriptions have had to rest on single specimens and at best the series are small. Added to this, specimens of *Apristurus* preserved in alcohol quickly become wrinkled and fragile. Measurements are difficult to make, and the body proportions and fin positions in the series measured appear to vary considerably within species.

So far as known, all species inhabit deep water, specimens for the most part being taken from depths of more than 600 m.

KEY TO WESTERN ATLANTIC *APRISTURUS*

- 1A. Denticles over most dorsolateral areas narrow, erect, not imbricate, their bases separated by distances greater than the diameter of a denticle base; a caudal crest of wide, imbricate denticles of about uniform size, their tips not pointed upward, forming a rather smooth surface, extending a short distance onto the lateral surface of the tail, the crest denticles in sharp contrast (see fig. 23) to the very sparsely scattered, narrow and erect denticles of the lateral surface of the tail; pelvic fins comparatively short, somewhat thickened, broadly ovate in shape; anal fin relatively high, its anterior and distal margins forming a continuous smooth curve ----- *Apristurus profundorum*
- 1B. Denticles over most dorsolateral surfaces moderately broad, close together, imbricate or at least very closely arranged with small spaces between bases; denticles of upper margin of tail not differing greatly in shape, size or density of arrangement from denticles of lateral surfaces of tail; pelvic fins comparatively long, lanceolate; anal fin either high or low but with its anterior margin and distal margin forming an angle, the two margins not rounded as a continuous curve ----- 2A or 2B
- 2A. Head comparatively narrow with narrow band of prominent mucous pores of underside of snout extending medially from front of mouth nearly to tip of snout in four or sometimes six longitudinal rows; tip of snout notably constricted at anterior end of nostrils; teeth comparatively large and sexually dimorphic ----- *Apristurus riveri*
- 2B. Head comparatively broad with a wide band of prominent mucous pores of underside of snout extending medially from front of mouth nearly to tip of snout in eight or more longitudinal rows; tip of snout not notably narrowed at nostrils; teeth comparatively small with no sexual dimorphism ----- 3A or 3B

3A. Second dorsal fin substantially greater in area than first dorsal fin; first dorsal fin origin usually behind posterior end of base of pelvic fins -----

Apristurus indicus

3B. First and second dorsal fins of nearly equal area; first dorsal fin origin over the middle of the pelvic base ----- *Apristurus laurussoni*

***Apristurus profundorum* (Goode and Bean), 1896**

Figures 7, 22, 23, 25, and 27; tables 1, 7, and 8.

The type specimen of *A. profundorum*, USNM 35646, is in quite poor condition and very fragile. The fins are frayed, the skin looks scuffed, and the general impression given is that denticles, pieces of skin, and pieces of fins must be missing. Actually very little is missing although there is no doubt that the specimen had been severely damaged either when captured or during 69 years of its existence as a preserved specimen. Some questions about this specimen came up during the course of preparation of a report on sharks (Bigelow, Schroeder, and Springer, 1953), and if my memory is correct it fell to my lot to reexamine it. Apparently my reexamination missed some of the important features, and I am thus primarily responsible for failure to note that the material studied and held to be *profundorum* in that report included two species.

A. profundorum is easily separated from the other three western Atlantic species by the characters given in the preceding key. Several differences also are evident from table 8 which shows ranges of measurements in the series examined. These ranges of measurements show a lesser distance from the tip of the snout to the origin of the first dorsal fin than in the other three western Atlantic species and a lesser distance from the tip of the snout to the origin of the second dorsal. The table also shows a wide degree of variation in proportions for all *Apristurus*.

The teeth of the type, an adult male, are in 25+25/25+25 rows, and the teeth of a smaller female specimen, MCZ 38299, are in 31+31/25+25 rows. The teeth are difficult to count because they are arranged in alternate series, and the number of functional series varies from about five near the symphysis to three or less at the corners of the jaw.

The type of *profundorum* was collected from 1,492 m. off Delaware Bay, and the specimens included in the series of five specimens measured here was collected by the M/V *Cap'n Bill II* at depths from 686 to 1,317 m. off New Jersey and New England.

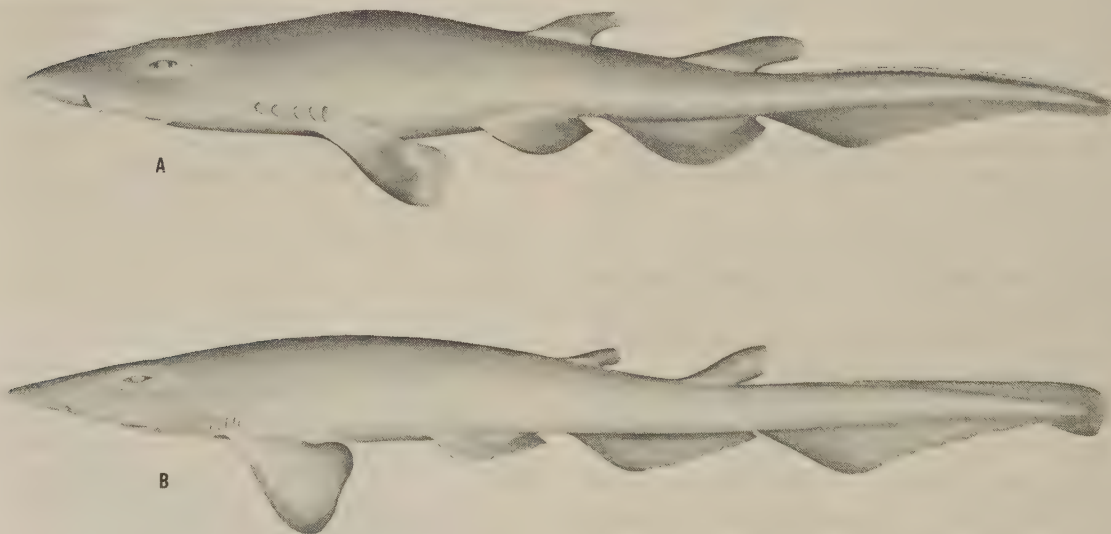


FIGURE 22.—A, *Apristurus profundorum* (Goode and Bean), drawn from a 390-mm. female, MCZ 38299; B, *Apristurus indicus* (Brauer), drawn from a 395-mm. female from M/V *Oregon* station 3586.

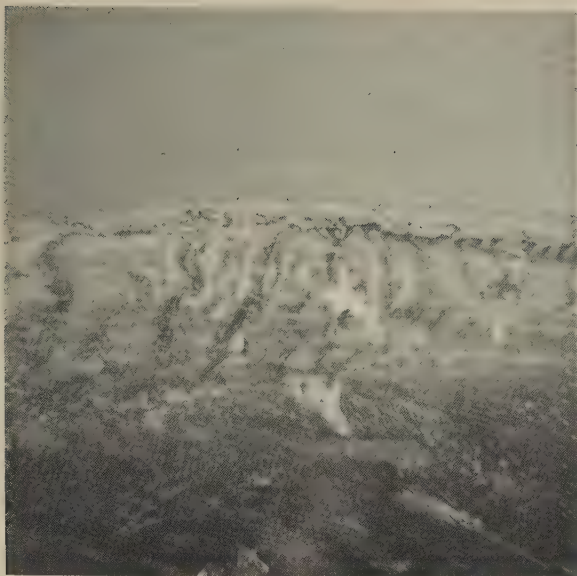


FIGURE 23.—Lateral view of portion of caudal fin of *Apristurus profundorum* (Goode and Bean), showing closely packed denticles on and near the upper margin of the fin and the widely spaced denticles on the lateral surfaces of the tail.

***Apristurus indicus* (Brauer), 1906**

Figures 9, 22, and 27; tables 1, 7, and 8.

It is clear that the western Atlantic specimens of *Apristurus* at hand may be divided into four groups on the basis of characters given in the preceding key. Three of these groups of specimens clearly represent respectively *Apristurus profundorum* (Goode and Bean), *A. riveri* Bigelow and Schroeder, and *A. laurussoni* (Saemundsson). The fourth group includes specimens referred to *Apristurus atlanticus* (Koefoed) by Bigelow and Schroeder (1948) and Bigelow, Schroeder, and Springer (1953). The specimens available for examination are about 40 examples from the Gulf of Mexico, the Caribbean, and adjacent Atlantic waters, most of them immature. All are referred to *Apristurus indicus* (Brauer) with some misgiving because *A. indicus* has been regarded as restricted to the Indian Ocean.

Koefoed states (1927) that *atlanticus* is related both to *profundorum* Goode and Bean, and *indicus* Brauer, but that it differs in having a larger eye. From Koefoed's measurements of the type, a 247-mm. specimen from the Atlantic near Gibraltar, it can be calculated that the orbit is 4.9 percent of the total length. Among the specimens referred here

to *A. indicus*, the orbit is 2.5 to 4.0 percent of the total length and in available specimens of other Atlantic species 2.2 to 3.9. Koefoed's figure of the type of *atlanticus* (1927, pl. 3, fig. 3) shows the second dorsal fin only slightly larger in area than the first. In Western Atlantic specimens of *A. indicus* the second dorsal fin has less than half the area of the first dorsal. Furthermore, Koefoed specifically states that the first and second dorsal fins of *atlanticus* are equally large.

The number of tooth rows in the western North Atlantic specimens of *A. indicus* at hand varies from 33+33/33+33 to 45+45/45+45. The teeth of these specimens are much smaller and more numerous than in *A. profundorum* and *A. riveri*. Although the teeth of *A. laurussoni* are slightly larger than in the *A. indicus* specimens, the difference is not great enough to be notable except on direct comparison of specimens of equal size.

***Apristurus riveri* Bigelow and Schroeder, 1944**

Figures 4, 5, 7, 10, 11, 24, and 27; tables 1, 7, and 8.

In one haul with a 40-foot shrimp trawl at M/V Oregon station 3586 off the Caribbean coast of Panama, five *Apristurus* of about equal size were taken. The haul was made in 860 to 914 m. A temperature determination at the bottom was not made at this station but in nearby stations the following temperatures were recorded: 366 m., 11.6° C; 457 m., 8.8° C; 750 to 768 m., 5° C. Four of the specimens collected were adults of *A. riveri*, one male and three females. The fifth specimen was an immature example of *A. indicus*. Of the three female *riveri*, one had short filamentous processes of egg cases protruding. In all three the cloacal area was surrounded by a flattened ring of white tissue. All had large eggs (10–12 mm. diameter) in the single ovary, and one had egg cases with eggs in both oviducts. The egg cases were about 50 mm. long, not including filaments, and about 15 mm. in greatest width. The shells appeared to be smooth surfaced. The egg shells were not completely formed or finished at their inner ends, and the nature of the processes at the posterior ends could not be determined, except that they were not the single tendrils at each corner found in *Scyliorhinus* but were more numerous and arranged as a filamentous fringe across the end of the case. The cases were greenish, semitransparent, and with some longitudinal lines of lighter color.

The uniformly flattened cloacal area was apparent as an unusual feature of the specimens only when they were fresh or were preserved in formalin. After transfer to alcohol this flattening disappeared.

The presence of an adult male in the haul also revealed the remarkable difference in tooth size and shape (fig. 10) between adult males and females. Although later collections produced another adult male from near Key West, the only immature specimens seen thus far have been females, so it has not been determined when the tooth dimorphism first appears.

The teeth in the six specimens examined are in $24+0+24/19+0+19$ to $29+0+29/22+0+21$ rows with no teeth at the symphysis in either jaw. The teeth of the females are generally tricuspid in the central portion of the jaws but have five, seven, or nine cusps toward the angles of the jaws. The number and shape of the teeth of females of the series described here are about as described for *A. riveri* by Bigelow and Schroeder (1944, 1948). Using the definition of series of teeth given earlier in this paper, however, the number of functional series in *riveri* is five or six. The tooth arrangement, as in other *Apristurus* or, for that matter, in all scyliorhinids, is in alternate series with series

defined as teeth arranged along a single line parallel with the axis of the jaw. This arrangement gives the appearance of diagonal rows (see fig. 11). It may be described also as Bigelow and Schroeder (1944) have done as an arrangement in quincunx.

In dealing with somewhat larger series than were available to Bigelow and Schroeder, some difficulties have appeared in the use of distances between gill openings and angles formed by the labial grooves as means for differentiating species, because of greater variation in the larger series. Among western Atlantic species the narrower head of *riveri* seems the most outstanding and reliable criterion for quick identification. The comparatively narrower head is shown quite clearly in figure 27. In *riveri* the band of pores on the underside of the snout is consistently narrower than in other western Atlantic species, generally being composed of about four rows of pores instead of eight or more.

The claspers of the adult males are rather short, reaching about 2.3 percent of total length beyond the tips of the pelvic fins, and quite stout. There are no hooks. The clasper siphons are also relatively short, extending only about 10 mm. in advance of the origin of the pelvics.

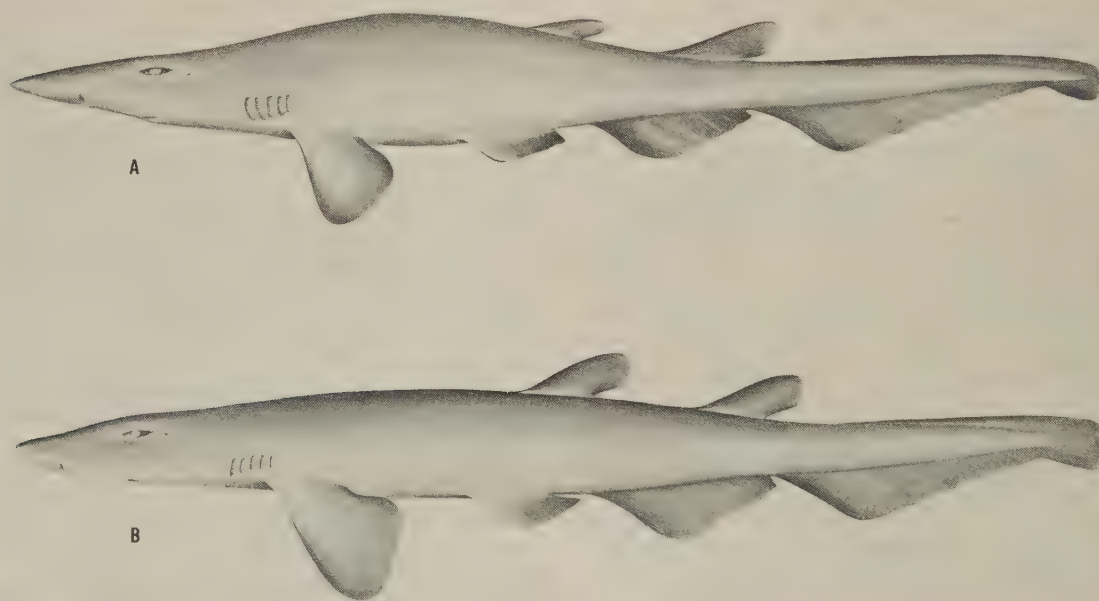


FIGURE 24.—A, *Apristurus riveri* Bigelow and Schroeder, drawn from a 400-mm. female from M/V Oregon station 3586; B, *Apristurus laurussoni* (Saemundsson), drawn from a 540-mm. male, MCZ 38406.

Saemundsson's only specimen, the type of *Scyllium laurussonii*, was a 673-mm. female. This specimen, which is in excellent condition, was examined through the courtesy of the Natural History Museum, Reykjavik, as a loan. It differs from the type specimen Goode and Bean of *Scylliorhinus profundorum* 1896, with respect to characters given in the preceding key.

The separation of the broadheaded *A. laurussoni* from the narrow-headed *A. riveri* and the separation of *A. laurussoni* from *A. profundorum* on the basis of the pelvic shape (see fig. 25) or the denticle distribution problem presents no difficulty except perhaps in very small specimens.

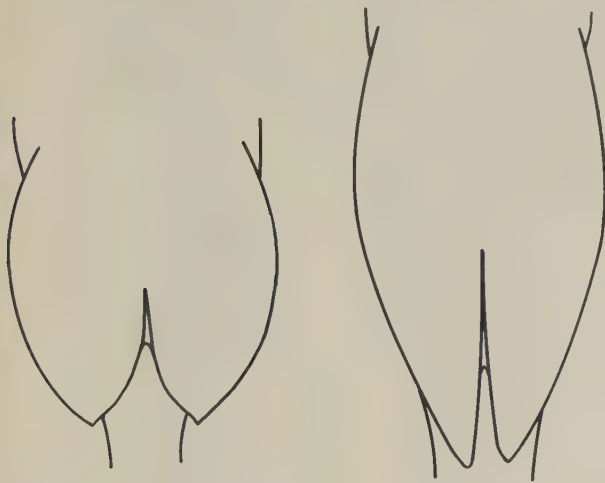


FIGURE 25.—Diagram to show shapes of pelvic fins: At left, *Apristurus profundorum*; at right, *Apristurus laurussoni*.

A. laurussoni differs from our specimens of *A. indicus* in having the two dorsal fins of approximately equal size. In *A. indicus* the first dorsal fin has about half the area of the second. Both *laurussoni* and *indicus* in the material examined are quite variable in number of tooth rows, number of vertebrae, and fin positions.

The teeth of *A. laurussoni* are small and comparatively numerous in 34+0+34/34+0+32 to 42+0+41/53+0+43 rows. The two largest males examined, 520 and 540 mm., are apparently immature, but there is no indication of sexual dimorphism in teeth in comparison with a 580-mm. female or the type, a 673-mm. female. Saemunds-

son (1922) noted that the teeth of the type are in 22 rows on each side of the symphysis. My count of the teeth of the type specimen is approximately 41 rows on each side. This difference is the result of a different method of counting rows. The alternate arrangement of teeth together with their generally small size makes routine tooth counting in *Apristurus* impractical. In many specimens the diagonal rows are very prominent and seem to be the logical ones to count. In our specimens if diagonal rows were counted, the tooth formula would be close to that given by Saemundsson.

It may be helpful to subsequent workers with the genus to note that Goode and Bean's type and only specimen of *profundorum* is an adult male while their illustration (1896, pl. 5, fig. 16) appears to be a female. Saemundsson's text references to illustrations on plate V (1922, pp. 173 and 200) for *Pristiurus Jensenii* and *Scyllium Laurussonii* are reversed, and the illustration of the lateral view of a shark in Bigelow and Schroeder (1948, fig. 38) captioned as the type of *profundorum* may not represent that species since the illustration shows either a female or a male with claspers not showing, while the type is a male with claspers extending past the tips of the pelvises.

Exclusive of the type which was collected from 560-m. depth near Vestmannaeyjar, off the southern coast of Iceland, I have examined about 25 specimens that I refer to the species. These are from the northern half of the Gulf of Mexico and from the Atlantic coast of the United States from latitude 40°40' N. (off Massachusetts) southward to 38°41' N. (off Delaware). Specimens were taken from depths of 760 to 1,460 meters.

Genus *Halaehurus* Gill, 1861

Type species—*Scyllium bürgeri* Müller and Henle, 1841, by original designation.

The group of scylliorhinid sharks usually assembled in the genus *Halaehurus* seems to include leftovers and poorly known species. It is in special need of nomenclatural revision. Changes can best be made in a general revision of the world's scylliorhinid genera, which will require more extensive collections than are available now.

The American representatives of *Halaehurus* have long and strong labial grooves along both upper and lower jaws and thus differ from American species of the genus *Scylliorhinus* which have weak and short labial folds only on the lower jaw. The

two South American species considered here both have patterns of dorsal saddles somewhat resembling those in *Scyliorhinus* and from this feature can be readily separated from *Apristurus*. They

have no caudal crests and so differ from *Galeus*. They differ from *Schroederichthys* in having caudal trunk sections somewhat shorter, in having much longer and more prominent labial folds, and



FIGURE 26.—A, *Halaelurus chilensis* (Müller and Henle), an immature male collected at Coquimbo Bay, at lat. 29°56' S., on the coast of Chile (the pelvic fin of this specimen has been damaged); B, *Halaelurus bivius* (Guichenot), collected near Puerto Montt, Chile, at lat. 41°54' S.

in having a reduction (in the larger specimens examined) in the number and size of the accessory cusps on the teeth of the lower jaw.

In many features the *Halaeburus* of the southern

part of South America resembles *Schroederichthys*. Dr. Elvira Siccardi who has examined many specimens from Argentina has called my attention (in personal communication) to several

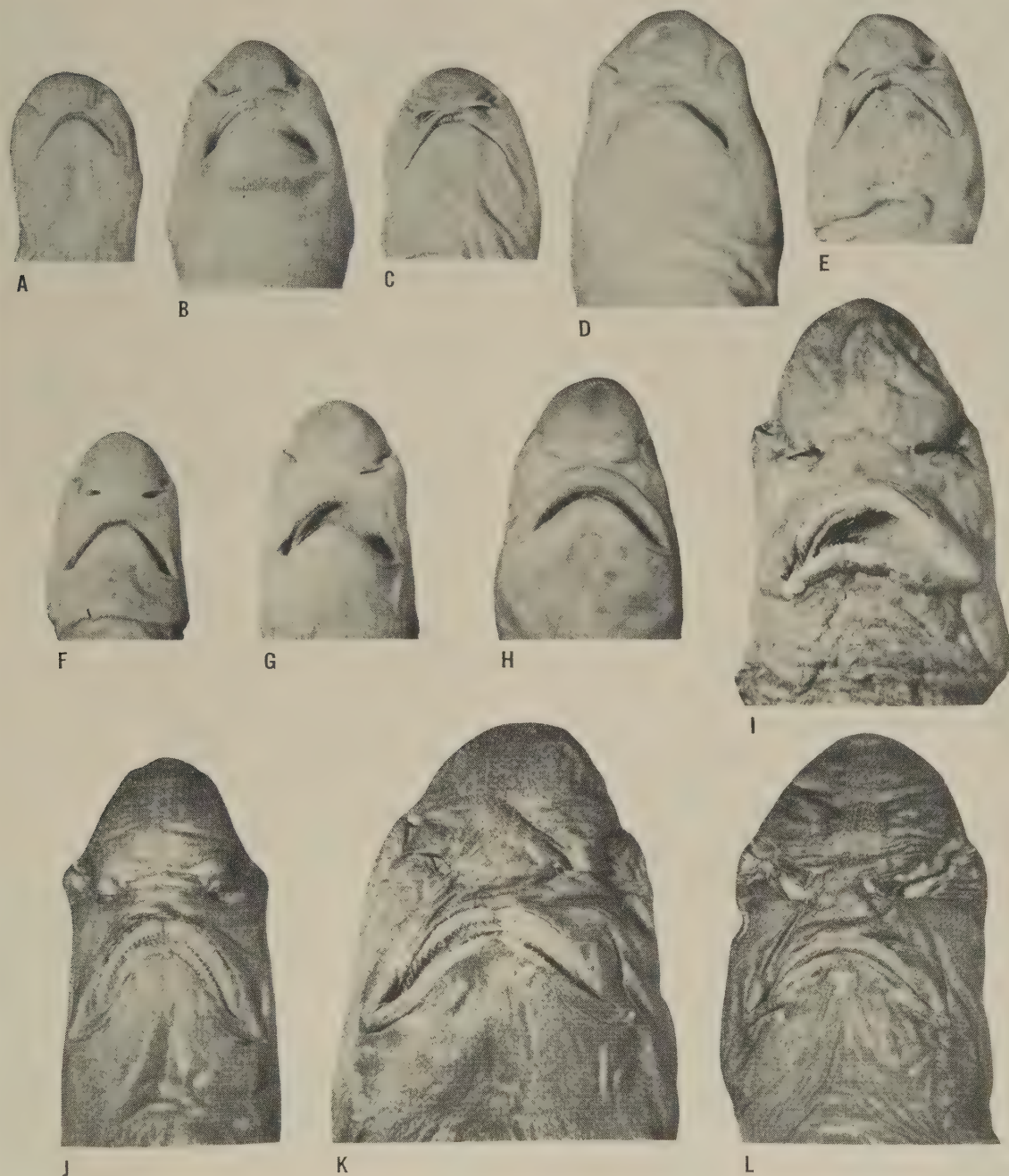


FIGURE 27.—Photographs of lower side of heads: A, *Scyliorhinus torrei*; B, *Scyliorhinus retifer*; C, *Scyliorhinus meadi*; D, *Scyliorhinus hesperius*; E, *Scyliorhinus boa*; F, *Galeus arae*; G, *Galeus cadenati*; H, *Galeus arae*; I, *Apristurus profundorum*; J, *Apristurus riveri*; K, *Apristurus laurussoni*; L, *Apristurus indicus*.

similarities such as the development of long, very slender nasal flaps in species of each genus (*H. bivius* and *S. tenuis*), the relatively short caudal lobes in combination with long postpelvic trunk in both groups, and certain somewhat subtle similarities in denticle structure.

Problems in connection with names to be applied to South American *Halaehurus* cannot be adequately treated here because of insufficient study material. My view that more species than *Halaehurus chilensis* (Guichenot, 1847) and *Halaehurus bivius* (Müller and Henle, 1841) are involved in the material described by various authors has been strengthened by discussions with Dr. Siccardi.

Some unresolved questions on the status of types add to the difficulties with nomenclature. The types of both *H. bivius* and *H. chilensis* are stuffed specimens. The specimen designated as the type of *bivius* by Günther (1870) is said to be from southwest Africa but Günther's description is not in close agreement with the earlier description of Müller and Henle (1841). The confusing synonymy of *bivius* can be seen in the treatment given in Norman's work (1937) on Patagonian fishes.

It seems probable that all of the accounts of South American *Halaehurus*, including this one, have been based on material quite inadequate to delineate species. Available material suggests that considerable differences in some characters may exist between young and adults of the same species. This makes the development of meaningful synonymy impractical. It is possible that both Berg (1895) and Lahille (1921, 1928) discussed the form here referred to *H. chilensis* under the name *bivium* or *bivius*. Vaillant's account (1891), under *Scyllium chilense* Guichenot, states that he believes *Scyllium bivium* Smith is not a distinct species, but goes on to state that all the small examples he had seen were females.

A more extensive study of these scyliorhinids should provide some answers of great interest to the phylogeny of carcharhinid sharks because these sharks, perhaps considered together with *Schroederichthys*, have more characters approaching the carcharhinid line than do other scyliorhinids. The longer jaw of *H. bivius* together with lower jaw spikelike teeth is a feature more familiar in the Carcharhinidae than in the Scyliorhinidae. The claspers and clasper siphons of

Schroederichthys bear many resemblances to those of the carcharhinids.

Halaehurus bivius (Müller and Henle), 1841

Figure 26; tables 7 and 8.

The specimens of *H. bivius* from Chile examined for this report are very easily separated from Chilean examples of *H. chilensis* by differences in general shape. As can be seen in the photographs (fig. 26), *H. chilensis* has a shorter head, a somewhat shorter and definitely less pointed snout, and a shorter and much less strongly arched jaw.

The specimens of *H. chilensis* examined were immature, showing a well-marked series of enlarged denticles in rows along the back, and in this differed from the adult *H. bivius* available for comparison. The specimens of *H. bivius*, however, had some enlarged dorsolateral denticles.

In direct comparison of *H. bivius* with *H. chilensis* specimens, it was noted that the nasal flaps of *H. bivius* were longer and narrower, the gill slits were somewhat longer, the anal fin base was somewhat longer (see table 7 and 8), and the denticles prevalent on dorsolateral surfaces had longer points.

Halaehurus chilensis (Guichenot), 1847

Figure 26; tables 7 and 8.

Based on specimens from the Pacific coast of South America, it appears that there are relatively great differences between *H. chilensis* and *H. bivius*. It should be noted, however, that all of the specimens of *H. bivius* seen were adult males while all the specimens referred to *H. chilensis* were immature.

SUMMARY AND COMMENT

To have accomplished its purpose, this study should have indicated some of the kinds of information about catsharks needed for an adequate revision of the family. Great variation within species, particularly in morphometrics, the occurrence of sexual dimorphism (at least in one species), and the finding of a new genus and several new species point to the need for more comprehensive collections from the continental slopes and from ocean basins as a basis for understanding the group.

Western Atlantic scyliorhinids all have been taken at depths where relatively cool temperatures prevail; and in the course of a more general study of the group, it will be interesting to note which,

if any, species enter relatively warmer areas or shallow-water areas. The discovery by Poll (1951) and Cadenat (1959) that the ovoviviparous condition and the oviparous condition both occur within a single genus (*Galeus*) points to the need for much more observation on life histories of catsharks.

The order in which genera are taken up in this paper is not intended to have any phylogenetic implication. *Galeus*, *Apristurus*, and *Schroederichthys*, as far as these are known at present, are quite compact groups of similar species and are separable from each other and from other of the world's scyliorhinid genera by many differences.

The separation of *Scyliorhinus* from *Halaelurus* and from some other genera of the Indo-Pacific region has, in the past, been based primarily upon differences in the arrangement of skin folds near the mouth, by the presence or absence of nasoral grooves, and by the relative development of anterior and posterior nasal valves. Keys to genera and also to species used by Garman (1913) and by Fowler (1941) emphasize these characters. I have given little descriptive space to them because they appear to be of little use for determination of west-

ern Atlantic species and also because they are somewhat variable in the specimens at hand. I have also had some difficulty in understanding the terminology. For example, Garman (1913) states that nasal cirri are absent or rudimentary in *Scyliorhinus*, but he separates *Poroderma*, an Indian Ocean genus, from *Scyliorhinus* in his key by the complete absence in *Poroderma* of a rudimentary nasal cirrus. This rudimentary cirrus, in the material I have examined, is merely a thickening of a portion of the anterior nasal flap, broader and thicker near the base of the flap, narrower and thinner near the posterior margin of the flap, but not extending at all beyond the edge of the flap. If one is familiar with the shape of nasal cirri of orectolobid sharks, this structure looks like a nasal cirrus entirely embedded in the flap. I find it difficult to accept the idea that this is necessarily a rudimentary structure and suspect that it may function in directing the flow of water past the nasal aperture.

Nevertheless, differences in skin structures near the mouth and nasal apertures may be of great usefulness in the practical description of species and as criteria for their identification, especially among Indo-Pacific forms.

TABLE 3.—Measurements of selected examples and type specimens of Atlantic *Scyliorhinus*

Species.....	<i>S. retifer</i> ORE 4153	<i>S. meadi</i> (type) USNM 188049	<i>S. hesperius</i> (type) USNM 187732	<i>S. boa</i> USNM 186195	<i>S. torrei</i> SB 2457	<i>S. canaliculus</i> USNM 195851	<i>S. stellaris</i> USNM 34352
Museum No. or Station No.							
	Mm. 465	Mm. 247	Mm. 415	Mm. 346	Mm. 270	Mm. 383	Mm. 370
Total length.....							
Tip of snout to—							
Anterior nasal aperture.....	12	8	11	10	6	7	9
Posterior nasal aperture.....	19	11	18	15	8	14	13
Front mouth.....	21	12	21	17	10	14	14
Eye.....	21	13	24	21	11	16	15
Gill I.....	74	36	69	50	35	46	52
Gill V.....	97	45	87	69	48	62	71
Origin pectoral.....	85	40	82	65	45	59	64
First dorsal fin.....	237	116	210	180	140	182	185
Pelvic fins.....	194	107	176	145	105	148	160
Anal fin.....	282	143	252	213	162	213	220
Second dorsal fin.....	314	153	283	238	188	251	242
Lower caudal fin.....	346	180	315	268	210	292	275
Upper caudal fin.....	354	185	320	274	215	298	285
Anus.....	203	112	190	155	114	156	170
Length upper caudal fin.....	108	63	95	72	55	85	85
Base first dorsal fin.....	28	15	26	23	18	25	26
Base second dorsal fin.....	24	13	21	17	12	20	24
Base anal fin.....	34	22	38	25	22	37	36
Distance between dorsal fins.....	52	26	44	37	33	46	32
Internasal distance.....	7	15	7	7	5	—	5
Length orbit.....	20	9	15	13	9	11	13
Length lower labial fold.....	9	5	7	3	5	12	8
Length upper labial fold.....							
Width mouth.....	34	20	34	25	19	22	25
Length mouth.....	20	11	14	15	10	9	16
Height gill I.....	9	6	7	6	5	9	6
Height gill V.....	4	4	4	4	2	4	3
Tip second dorsal to caudal.....	9	13	9	7	10	20	13
Tip pelvic to second dorsal.....	71	25	59	48	49	59	40
Tip pelvic to anal.....	44	13	33	31	25	21	22
Tip pelvic to lower caudal.....	106	55	95	86	76	100	77
Length outer margin pectoral.....	70	33	62	45	26	46	44
Length anterior margin first dorsal.....	45	25	41	32	22	33	39
Length anterior margin second dorsal.....	34	19	31	25	13	27	34
Length anterior margin anal.....	30	21	33	24	20	27	29
Distance eye to spiracle.....	3	3	3	3	2	3	4

TABLE 4.—Range of total lengths and range of measurements expressed as percent of total length in western Atlantic *Scyliorhinus*

Species.....	<i>S. retifer</i> 10 173-465	<i>S. meadi</i> 5 183-264	<i>S. hesperius</i> 13 160-466	<i>S. boa</i> 7 143-346	<i>S. torrei</i> 7 129-270
Number of specimens measured.....					
Length range in millimeters.....					
Tip of snout to—	Percent	Percent	Percent	Percent	Percent
Anterior nasal aperture.....	2.3- 3.4	3.0- 3.8	2.3- 4.0	2.5- 3.5	1.4- 2.2
Posterior nasal aperture.....	3.6- 4.7	4.2- 4.5	3.7- 5.1	3.8- 4.9	2.7- 3.9
Front mouth.....	4.4- 5.8	4.4- 4.9	4.5- 5.7	4.2- 5.6	3.5- 4.7
Eye.....	4.5- 6.1	5.3- 6.0	5.0- 6.8	5.2- 6.3	4.1- 5.4
Gill I.....	14.1-16.5	13.1-15.8	14.5-16.6	13.7-16.0	13.0-14.7
Gill V.....	18.1-22.2	18.6-21.6	18.9-21.5	18.0-20.4	16.4-18.0
Origin pectoral.....	16.4-20.7	16.7-20.0	17.7-19.8	16.2-18.8	15.4-17.2
First dorsal fin.....	45.7-51.1	46.3-48.5	46.9-53.7	45.5-52.0	44.9-51.8
Pelvic fins.....	39.6-41.8	40.4-42.1	39.5-44.4	38.9-41.9	33.2-39.5
Anal fin.....	56.5-60.7	55.7-57.6	54.4-62.5	53.8-61.6	54.2-60.0
Second dorsal fin.....	62.5-67.5	62.8-64.8	61.8-69.1	63.6-68.9	63.6-69.6
Lower caudal fin.....	72.3-76.7	71.5-75.0	73.0-77.4	72.7-78.2	73.6-78.5
Upper caudal fin.....	71.7-78.2	73.6-75.9	74.4-79.3	74.8-79.5	75.2-79.6
Anus.....	41.0-44.4	43.2-45.5	41.2-51.0	40.1-44.8	37.9-42.2
Length upper caudal fin.....	21.6-25.4	25.2-28.0	20.7-27.5	19.9-25.2	20.4-24.0
Base first dorsal fin.....	5.5- 7.0	5.8- 6.8	5.6- 6.7	5.4- 6.8	5.9- 7.0
Base second dorsal fin.....	4.5- 5.8	5.3- 6.3	4.3- 5.2	4.4- 5.8	4.2- 4.7
Base anal fin.....	7.2- 9.1	7.8- 9.5	7.2- 9.2	7.2- 9.3	7.3- 9.4
Distance between dorsal fins.....	10.6-11.9	10.5-11.6	9.2-11.3	10.3-13.7	10.9-14.5
Internasal distance.....	1.5- 2.3	5.8- 6.8	1.7- 2.7	1.8- 2.8	1.6- 2.3
Length orbit.....	3.2- 4.3	2.6- 3.8	3.1- 4.7	2.9- 4.3	3.1- 3.5
Length lower labial fold.....	1.3- 2.1	1.6- 2.3	0.9- 1.9	0.4- 1.8	1.2- 2.0
Length upper labial fold.....					
Width mouth.....	6.3- 8.1	7.4- 8.9	6.9- 8.8	5.8- 7.8	6.1- 7.8
Length mouth.....	2.8- 4.5	3.3- 4.3	3.3- 4.4	2.8- 4.0	3.5- 5.5
Height gill I.....	1.6- 2.3	1.1- 2.6	1.5- 2.5	1.3- 1.9	1.6- 2.3
Height gill V.....	0.6- 1.2	0.5- 1.3	0.6- 1.5	0.6- 1.2	0.2- 1.2
Tip second dorsal to caudal.....	1.8- 3.7	2.7- 4.7	1.7- 4.2	2.0- 4.9	2.7- 4.7
Tip pelvic to second dorsal.....	13.6-15.9	10.5-13.2	9.6-15.4	13.0-16.3	14.7-18.2
Tip pelvic to anal.....	6.8-10.7	5.8- 8.4	4.3-10.2	6.3-11.5	6.2-10.1
Tip pelvic to lower caudal.....	21.3-25.6	21.1-25.0	20.8-25.4	22.3-26.6	24.6-28.2
Length outer margin pectoral.....	11.4-15.0	10.9-13.6	10.7-14.9	11.8-13.7	8.5-11.3
Length anterior margin first dorsal.....	8.1-10.0	8.8-10.6	7.5-10.1	8.0-10.4	7.8- 8.6
Length anterior margin second dorsal.....	5.7- 7.7	6.8- 8.7	5.7- 8.2	5.4- 7.9	4.2- 5.7
Length anterior margin anal.....	5.3- 8.2	6.8- 9.1	5.8- 9.2	6.9- 8.3	5.5- 7.4
Distance eye to spiracle.....	0.4- 1.2	1.1- 1.6	0.7- 1.5	0.7- 1.3	0.7- 1.2

TABLE 5.—Measurements of type specimens of *Schroederichthys*, *Galeus cadenati* and selected examples of *Galeus arae*

Species.....	<i>S. maculatus</i> (type) USNM 185556	<i>S. tenuis</i> (type) USNM 188052	<i>Galeus arae</i> S.B. 2458	<i>G. arae</i> USNM 198164	<i>G. cadenati</i> (type) ORE 3592
Museum No. or Station No.....					
Total length.....	Mm. 328	Mm. 230	Mm. 290	Mm. 368	Mm. 303
Tip of snout to—					
Anterior nasal aperture.....	8	3	12	14	12
Posterior nasal aperture.....	11	7	14	18	15
Front mouth.....	14	9	18	22	20
Eye.....	15	10	20	25	22
Gill I.....	43	24	42	59	53
Gill V.....	53	32	53	75	61
Origin pectoral.....	50	30	52	73	57
First dorsal fin.....	126	82	131	156	133
Pelvic fins.....	100	69	115	144	109
Anal fin.....	172	120	165	214	151
Second dorsal fin.....	201	136	183	233	186
Lower caudal fin.....	260	179	210	270	210
Upper caudal fin.....	265	182	206	267	210
Anus.....	104	71	126	162	120
Length upper caudal fin.....	60	38	85	100	90
Base first dorsal fin.....	14	10	14	17	12
Base second dorsal fin.....	18	15	14	17	16
Base anal fin.....	24	21	30	32	45
Distance between dorsal fins.....	65	42	36	61	39
Internasal distance.....	8	6	8	11	8
Length orbit.....	11	7	10	13	9
Length lower labial fold.....	4	4	5	8	5.5
Length upper labial fold.....	4	3	3	5	4
Width mouth.....	19	13	20	26	21
Length mouth.....	11	6	12	15	12
Height gill I.....	5	4	5	6	4
Height gill V.....	2	2	3	3	3
Tip second dorsal to caudal.....	36	24	3	10	5
Tip pelvic to second dorsal.....	71	47	37	49	31
Tip pelvic to anal.....	42	30	20	24	2
Tip pelvic to lower caudal.....	135	92	63	81	59
Length outer margin pectoral.....	32	22	31	42	42
Length anterior margin first dorsal.....	23	18	21	29	30
Length anterior margin second dorsal.....	29	20	21	24	25
Length anterior margin anal.....	18	14	16	23	26
Distance eye to spiracle.....	3	2	3	4	4

TABLE 6.—Range of total lengths and measurements expressed as percent of total length in *Schroederichthys* and *Galeus*

Species.....	<i>S. maculatus</i>	<i>S. tenuis</i>	<i>Galeus arae</i>	<i>G. arae</i>	<i>G. cadenati</i>	<i>G. melastomus</i>
Number of specimens measured.....	49	2	10	4	10	5
Length range in millimeters.....	145-342	180-230	190-321	269-368	273-348	313-635
Tip of snout to—	Percent	Percent	Percent	Percent	Percent	Percent
Anterior nasal aperture.....	1.4- 2.4	1.3- 1.7	3.1- 4.1	3.4- 3.9	3.2- 5.1	3.2- 4.8
Posterior nasal aperture.....	2.4- 3.9	3.0- 3.3	4.3- 5.2	4.5- 5.2	4.6- 5.8	4.2- 6.7
Front mouth.....	3.1- 4.7	3.9- 3.9	5.3- 7.1	6.0- 6.9	6.0- 7.3	6.3- 8.6
Eye.....	3.7- 5.2	4.4- 4.4	5.3- 7.5	5.9- 7.8	6.3- 7.6	6.3- 8.3
Gill I.....	9.9-13.1	10.4-11.1	13.8-16.0	14.9-16.7	15.5-18.5	12.6-17.5
Gill V.....	12.9-17.0	13.9-14.4	16.3-19.8	20.1-20.7	18.2-22.2	17.2-23.0
Origin pectoral.....	12.0-16.3	13.0-13.3	15.3-19.3	19.0-20.7	16.7-21.8	16.7-22.1
First dorsal fin.....	34.7-40.8	34.4-35.6	42.4-47.3	40.9-43.4	43.2-47.9	44.9-48.2
Pelvic fins.....	28.9-33.6	29.4-30.0	37.2-42.0	34.6-39.1	34.5-40.2	36.9-39.6
Anal fin.....	49.4-54.5	49.4-52.2	50.9-56.9	52.7-58.2	49.8-55.6	52.1-53.9
Second dorsal fin.....	58.3-62.6	57.2-59.2	59.0-67.7	59.8-63.3	60.1-64.7	61.5-63.9
Lower caudal fin.....	77.5-82.8	77.7-77.8	68.8-74.1	68.8-74.7	69.0-75.1	69.4-70.6
Upper caudal fin.....	79.3-83.5	79.1-79.4	67.5-72.0	68.4-74.5	69.3-75.1	70.0-72.5
Anus.....	28.7-36.4	30.5-30.9	39.8-46.3	39.8-44.0	39.5-45.5	40.3-42.8
Length upper caudal fin.....	15.9-20.7	16.5-20.5	28.0-31.6	26.2-30.1	24.5-29.7	27.9-30.2
Base first dorsal fin.....	3.5- 5.1	4.4- 4.4	4.2- 5.9	4.3- 5.1	4.9- 6.3	4.4- 5.1
Base second dorsal fin.....	5.2- 8.1	6.1- 6.5	4.4- 5.7	4.1- 5.2	5.0- 6.3	4.6- 5.4
Base anal fin.....	6.6- 9.0	7.8- 9.1	10.3-13.6	8.7- 9.5	13.2-15.0	12.8-15.5
Distance between dorsal fins.....	17.2-20.0	18.3-19.4	11.3-12.9	14.1-16.6	12.3-14.7	10.9-14.0
Internasal distance.....	1.9- 2.5	2.4- 2.5	2.5- 3.3	3.0- 3.3	2.4- 3.2	2.4- 3.5
Length orbit.....	2.7- 3.5	3.0- 3.1	3.4- 3.9	3.1- 3.7	3.0- 4.0	3.6- 4.5
Length lower labial fold.....	0.8- 1.7	1.7- 1.7	1.4- 2.2	1.7- 2.6	1.6- 2.2	1.3- 1.9
Length upper labial fold.....	0.6- 1.2	1.3- 1.7	1.0- 1.5	1.4- 2.0	1.3- 1.7	1.0- 1.6
Width mouth.....	5.2- 6.8	5.7- 6.1	6.2- 7.5	7.1- 9.2	6.6- 9.1	6.2- 7.9
Length mouth.....	1.8- 3.9	2.6- 2.8	3.2- 4.3	3.0- 4.1	3.2- 5.5	3.3- 5.4
Height gill I.....	1.2- 2.1	1.1- 1.7	1.3- 2.1	1.1- 1.7	1.3- 2.1	1.9- 2.8
Height gill V.....	0.3- 0.7	0.4- 0.7	0.6- 1.3	0.6- 1.1	0.7- 1.3	0.9- 1.4
Tip second dorsal to caudal.....	9.6-12.9	10.4-12.2	0.2- 1.5	1.5- 2.7	0.0- 2.2	0.5- 1.3
Tip pelvic to second dorsal.....	18.4-23.1	19.4-20.4	8.8-12.6	10.4-13.3	9.8-11.9	10.2-14.2
Tip pelvic to anal.....	9.3-13.4	12.2-13.1	1.6- 6.7	4.8- 7.1	0.7- 3.2	1.3- 3.6
Tip pelvic to lower caudal.....	37.2-42.0	40.0-40.0	18.4-21.7	19.7-22.0	17.9-22.6	19.5-20.4
Length outer margin pectoral.....	8.2-11.8	9.4- 9.6	10.5-12.2	9.9-11.9	12.9-15.6	11.9-13.2
Length anterior margin first dorsal.....	6.1- 8.4	7.2- 7.8	7.2- 8.3	6.3- 7.9	8.5-10.5	7.7- 8.9
Length anterior margin second dorsal.....	6.8- 9.9	8.7- 8.9	7.0- 8.0	6.1- 6.9	7.9- 9.2	7.6- 8.9
Length anterior margin anal.....	3.4- 6.8	6.1- 7.2	5.5- 8.0	5.7- 6.2	6.4- 8.6	6.4- 8.1
Distance eye to spiracle.....	0.5- 1.5	0.8- 0.9	0.8- 1.5	0.9- 1.5	1.1- 1.4	0.7- 1.3

TABLE 7.—Measurements of a type specimen of *Apristurus* and of selected examples of *Apristurus* and *Halaelurus*

Species.....	<i>A. profundorum</i>	<i>A. indicus</i>	<i>A. riveri</i>	<i>A. laurussoni</i>	<i>H. bivius</i>	<i>H. chilensis</i>
Museum No. or other designation.....	MCZ 38299	ORE 3654	ORE 3586	MCZ 38406	Coast Chile 42° S.	Coast Chile 30° S.
	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.
Total length.....	390	303	430	540	625	365
Tip of snout to—						
Anterior nasal aperture.....	21	18	20	24	—	—
Posterior nasal aperture.....	34	25	30	36	—	—
Front mouth.....	40	31	35	46	22	12
Eye.....	46	33	46	52	—	—
Gill I.....	85	67	85	110	100	55
Gill V.....	104	78	109	130	128	68
Origin pectoral.....	99	76	105	124	120	64
First dorsal fin.....	170	152	210	252	270	140
Pelvic fins.....	150	125	180	230	—	—
Anal fin.....	192	151	230	295	—	—
Second dorsal fin.....	212	185	270	338	—	—
Lower caudal fin.....	243	206	296	378	—	—
Upper caudal fin.....	253	210	308	390	509	293
Anus.....	164	139	195	257	250	135
Length upper caudal fin.....	115	93	123	148	116	72
Base first dorsal fin.....	23	12	17	35	39	27
Base second dorsal fin.....	29	17	27	35	42	32
Base anal fin.....	57	53	61	85	62	29
Distance between dorsal fins.....	28	25	33	47	100	60
Internasal distance.....	18	14	17	20	17	8
Length orbit.....	13	10	15	16	17	10
Length lower labial fold.....	15	6	12	14	17	8
Length upper labial fold.....	11	10	10	19	20	8
Width mouth.....	34	23	23	48	40	27
Length mouth.....	20	11	20	24	25	13
Height gill I.....	7	2	11	9	10	6
Height gill V.....	7	2	8	5	6	4
Tip second dorsal to caudal.....	-10	-3	—	—	—	—
Tip pelvic to second dorsal.....	30	27	38	44	—	—
Tip pelvic to anal.....	—	-4	8	—	—	—
Tip pelvic to lower caudal.....	56	49	70	85	—	—
Length outer margin pectoral.....	40	34	48	70	76	45
Length anterior margin first dorsal.....	34	15	27	50	64	40
Length anterior margin second dorsal.....	45	25	36	50	68	45
Length anterior margin anal.....	20	22	30	50	47	27
Distance eye to spiracle.....	6	3	4	6	—	—

TABLE 8.—Range of total lengths and measurements expressed as percent of total length in *Apristurus* and *Halaelurus*

Species.....	<i>A. profundorum</i>	<i>A. indicus</i>	<i>A. riveri</i>	<i>A. laurussoni</i>	<i>H. bivius</i>	<i>H. chilensis</i>
Number of specimens measured.....	5	12	6	10	2	2
Length range in millimeters.....	230-390	235-475	338-460	212-580	555-625	365-392
Tip of snout to—	Percent	Percent	Percent	Percent	Percent	Percent
Anterior nasal aperture.....	4.8- 7.2	4.2- 5.9	4.7- 6.3	3.8- 5.4		
Posterior nasal aperture.....	7.4-10.4	6.6- 9.3	6.5- 8.3	6.1- 8.3		
Front mouth.....	8.7-10.9	7.6-11.2	7.4-10.0	7.5- 9.6	3.5- 3.8	3.3- 3.3
Eye.....	10.9-13.0	8.4-11.9	10.0-11.8	8.0-11.5		
Gill I.....	19.1-22.8	16.8-22.0	18.3-21.3	17.0-21.4	15.1-16.0	15.2-16.6
Gill V.....	23.5-26.7	21.5-25.8	22.2-25.3	22.2-26.8	18.4-20.5	18.3-21.4
Origin pectoral.....	23.0-25.4	20.2-25.1	21.0-24.4	21.6-25.8	18.0-19.2	17.5-20.4
First dorsal fin.....	40.9-43.6	47.9-51.8	45.6-48.9	43.4-51.2	40.5-43.2	38.4-38.6
Pelvic fins.....	38.3-41.6	38.2-42.7	39.4-42.7	40.1-47.8		
Anal fin.....	46.1-50.8	49.5-53.6	47.9-53.6	47.5-57.9		
Second dorsal fin.....	53.9-58.3	58.5-63.6	56.8-62.8	59.0-67.2		
Lower caudal fin.....	61.3-64.4	65.6-71.8	64.5-68.8	63.6-72.4		
Upper caudal fin.....	64.8-66.9	67.2-72.6	65.1-71.6	66.0-79.3	78.0-81.4	74.7-80.3
Anus.....	42.0-44.3	42.8-49.6	43.5-47.7	42.9-51.2	37.9-40.0	37.0-38.2
Length upper caudal fin.....	29.5-33.5	29.3-32.2	28.3-32.1	25.9-31.0	18.6-22.0	19.7-20.2
Base first dorsal fin.....	4.8- 7.0	3.4- 4.8	3.3- 4.4	4.5- 6.6	5.6- 6.2	7.4- 7.7
Base second dorsal fin.....	6.5- 7.4	5.0- 6.8	5.4- 6.8	4.8- 7.3	6.7- 8.3	8.8- 9.2
Base anal fin.....	13.2-14.8	13.5-18.3	13.0-18.0	13.8-16.9	9.4- 9.9	7.9- 8.9
Distance between dorsal fins.....	6.0- 9.6	6.0- 8.8	5.9- 8.9	8.7-10.8	16.0-16.2	16.4-16.6
Internasal distance.....	3.6- 4.8	3.7- 4.7	3.7- 4.3	3.6- 5.0	2.3- 2.7	2.0- 2.2
Length orbit.....	2.2- 3.3	2.5- 4.0	3.3- 3.5	2.7- 3.9	2.7- 2.9	2.7- 2.8
Length lower labial fold.....	2.0- 3.8	1.6- 2.6	2.2- 2.8	2.1- 3.2	2.2- 2.7	2.2- 2.6
Length upper labial fold.....	1.6- 2.8	1.9- 3.9	2.2- 2.7	3.1- 3.9	2.7- 3.2	2.2- 2.6
Width mouth.....	5.7- 8.7	6.3- 9.4	5.3- 7.3	6.1-10.0	5.8- 6.4	7.4- 7.7
Length mouth.....	3.9- 5.1	3.3- 4.8	3.2- 5.2	3.3- 5.9	5.0- 5.6	3.6- 3.6
Height gill I.....	0.9- 2.0	1.0- 2.2	2.2- 2.6	0.8- 2.3	1.4- 1.6	1.6- 2.0
Height gill V.....	0.9- 1.6	0.4- 1.3	0.9- 1.9	0.5- 1.1	0.7- 1.0	0.1- 1.3
Tip second dorsal to caudal.....		0- 1.3	0- 3.5	0- 1.8		
Tip pelvic to second dorsal.....	5.2- 9.3	6.7-12.6	7.4-11.5	6.6-10.8		
Tip pelvic to anal.....	-3.0- 2.0	-1.5- 2.5	0- 2.0	0- 1.7		
Tip pelvic to lower caudal.....	13.0-16.2	14.9-18.1	14.8-16.3	14.1-18.4		
Length outer margin pectoral.....	8.8-10.9	8.4-11.6	9.8-11.9	8.3-13.0	11.7-12.2	12.0-12.3
Length anterior margin first dorsal.....	7.0- 8.9	4.2- 7.5	5.4- 7.4	7.1- 9.3	9.0-10.2	10.4-11.0
Length anterior margin second dorsal.....	7.8-11.5	7.2- 9.7	8.4-11.0	7.4- 9.9	10.9-12.6	12.0-12.3
Length anterior margin anal.....	5.1- 6.0	5.8- 9.1	6.5- 8.1	7.1- 9.3	7.4- 7.5	7.4- 8.2
Distance eye to spiracle.....	0.9- 1.6	0.8- 1.3	0.9- 1.2	0.9- 1.2		

A look at the literature on scyliorhinids of the Indo-Pacific and an examination of very few specimens suggests that studies of Indo-Pacific species will provide a better basis for estimates of phylogenetic relationships than can be made from Atlantic species alone. The Atlantic material does suggest, however, that more detailed study of dentition would be desirable, especially with attention to tooth development. For this review no positive evidence on scyliorhinid migration and very little information on habit patterns were found. Further studies of species found in the higher latitudes off South America appear most promising for estimating the course of scyliorhinid phylogeny.

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these were prepared by Mildred Carrington. With a decision to expand the paper to cover catsharks of the western Atlantic region, other illustrations were prepared by Mary Wagner.

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SURVEY OF PELAGIC FISHES OF THE CALIFORNIA CURRENT AREA

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ABSTRACT

The pelagic fishes off central California to central Baja California were surveyed with four kinds of nekton-collecting nets. Construction and operation of one of these nets, the collapsible midwater beam trawl, are described. The survey was made during eight cruises between May 1961 and March 1963. More than 189 fish species and about 52,000 specimens were taken.

The number and size range of specimens at each station of capture are listed for all the species; charts of the location of capture are given for most species; and several species are illustrated. The records for many of the species are annotated with remarks and data on taxonomy, range, ecology, and ontogeny.

A survey of the nekton off central California to central Baja California was begun in January 1962 by the Life History and Taxonomy Program of the Bureau of Commercial Fisheries, California Current Resources Laboratory, La Jolla, Calif. The purpose of this survey was twofold: to begin to learn what larger pelagic organisms (primarily fishes) occur in the area sampled and to investigate certain aspects of the life history of the hake (*Merluccius*), a species of potential commercial importance. This report presents a list of the more than 189 species of fishes taken on the survey, with annotations on life history, distribution, and taxonomy for many of the species. A subsequent report will give data obtained on the hake other than records of occurrence. The invertebrates collected were placed in the Marine Invertebrate Collection of Scripps Institution of Oceanography.

Since development of the Isaacs-Kidd midwater trawl (IKMWT) in 1950, a large number of tows have been made in the Pacific with this type of

net (Aron, 1960; King and Iversen, 1962; Clarke, 1963). Specimens collected with the IKMWT have been deposited in various museums, but only the collections made by Aron (1960) have been reported comprehensively. Wisner (1962) gave a list of species and numbers of each taken in 14 IKMWT tows during Operation "Wigwam" off Baja California.

In addition to the 10-ft. IKMWT, this survey used a 10- by 14-ft. collapsible midwater beam trawl (CMWBT), to be described in a later section, a 5- by 5-ft. nekton net (Blackburn, 1960: 53-55), and the large Cobb Mark-II pelagic trawl of about 70- by 80-ft. mouth opening (McNeely, 1963).

After examining the catches made by the various nets, it seems obvious that none of the nets used is adequate by itself to sample the nekton of the bathypelagic area and that a variety of nets should be used in future surveys. The Cobb trawl, because of its large size, is more efficient than other nets used in catching the larger and more elusive organisms. Direct comparisons of the catching efficiencies of these nets are not made in this report, because of the many variables that entered into the survey.

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CRUISES

This report has used the collections from eight cruises made from May 1961 through March 1963 (table 1). Four cruises were made by the Bureau's R/V *Black Douglas* (B6203, B6204, B6212, and B6303); two by the R/V *John N. Cobb* through co-operation of the Bureau of Commercial Fisheries Exploratory Fishing Base, Seattle, Wash. (C6208 and C6303); and two cruises by the R/V *Horizon* through cooperation of Scripps Institution of Oceanography (H6105 and H6204). The cruises are briefly summarized below. The stations at which no fish were caught are listed below as "negative tows." The depths of tows in meters and the number of tows (in parentheses) follow the information on the types of nets used.

Cruise H6105: R/V *Horizon*; May 27-28, 1961; 135 to 160 km. (85 to 100 miles) west of San Diego, Calif.; 5 tows with IKMWT: 18 (2), 178 (1), 705-1,093 (2).

Cruise B6203: R/V *Black Douglas*; March 2-30, 1962; San Francisco, Calif., to south-central Baja

California, up to 970 km. (600 miles) seaward; 29 tows with CMWBT and 2 tows with 5- x 5-ft. nekton net: 9-132 (6), 256-264 (9), 419-423 (15), 622 (1); negative tows, stations 70.80a, 70.130, 80.51, 80.80, 90.150; other cruise work, oblique tows with 1-m. standard plankton nets and 2-m. stramin nets, bottom trawls with 16-ft. otter trawls.

Cruise H6204: R/V *Horizon*; March 16 to April 24, 1962; San Francisco, Calif., to Cedros Island Baja California, up to 970 km. (600 miles) seaward; 48 tows with IKMWT: 148 (1), 298 (25), 410 (1), 1,490 (1), 1,676 (14), 1,863 (4), 2,234 (2).

Cruise B6204: R/V *Black Douglas*; April 6-7, 1962; 16 to 19 km. (10 to 12 miles) SW. of San Diego, Calif.; 6 tows with CMWBT: 38 (3), 282 (1), 564 (2); other cruise work, oblique tows with 1-m. standard plankton net.

Cruise C6208: R/V *John N. Cobb*; August 6 to September 7, 1962; San Francisco, Calif., to Ensenada, Baja California, up to 970 km. (600 miles) seaward; 61 tows with *Cobb* pelagic trawl Mark II: surface-92 (34), 183-296 (4), 366-403 (23); negative tows, stations 90.49a, 91.39c.

TABLE 1.—Pelagic survey station data

[Asterisks indicate that values are approximate]

Station	Vessel and cruise	Se- quence occu- pied	Location of haul				Date	Time of tow (P.s.t.)		Depth of bottom	Tow- ing wire out	Depth fished	Type of haul
			Start		End			Start	End				
			Lat. N.	Long. W.	Lat. N.	Long. W.							
60.55	C6208	91	37°45.5'	123°20.3'	37°42.0'	123°23.8'	6 Aug. 1962	Hour 1750	Hour 2000	M. 1, 189-2, 379	M. 1, 052	M. *366	Oblique.
60.60	H6204	39	37°36.6'	123°37.0'			26-27 Mar. 1962	2024	0005	3, 331	5, 032	*1, 863	Horizontal.
60.60	C6208	92	37°37.0'	123°37.0'	37°42.2'	123°34.0'	7 Aug. 1962	0655	0915	3, 111-2, 928	1, 052	*366	Oblique.
60.70	H6204	41	37°07.9'	124°25.0'			27 Mar. 1962	0613	0750	3, 843	805	*298	Horizontal.
60.70	C6208	93	37°22.2'	124°12.3'	37°17.8'	124°15.0'	7 Aug. 1962	1440	1657	3, 843	1, 052	*366	Oblique.
60.80	H6204	42	36°54.0'	125°04.4'			27 Mar. 1962	1250	2000	4, 117	6, 039	*2, 234	Horizontal.
60.80	C6208	94	36°55.5'	125°04.0'	37°03.5'	124°59.0'	7-8 Aug. 1962	2225	0025	4, 209	1, 052	*366	Oblique.
60.90	H6204	43	36°34.4'	125°46.0'			28 Mar. 1962	0012	0147	4, 392	805	*298	Horizontal.
60.90	C6208	95	36°36.0'	125°38.4'	36°38.6'	125°34.0'	8 Aug. 1962	0655	0905	4, 484	1, 052	*366	Oblique.
60.100	H6204	45	36°17.0'	126°31.0'			28 Mar. 1962	0809	1226	4, 502	4, 032	*1, 863	Horizontal.
60.100	C6208	96	36°15.0'	126°32.0'	36°12.8'	126°25.0'	8 Aug. 1962	1545	1800	4, 575	1, 052	*366	Oblique.
60.120	B6203	20	35°27.2'	128°00.0'			13 Mar. 1962	0035	0400	4, 575	604	*1, 419	Do.
60.120	H6204	46	35°35.2'	127°54.0'			28-29 Mar. 1962	2205	0010	3, 697	805	*298	Horizontal.
60.140	H6204	48	34°57.0'	129°19.0'			29 Mar. 1962	1022	1511	4, 602	5, 032	*1, 863	Do.
60.160	B6203	21	34°19.0'	130°39.5'			13-14 Mar. 1962	2310	0210	5, 124	604	*423	Oblique.
60.160	H6204	50	34°16.0'	130°41.5'			29-30 Mar. 1962	2330	0110	4, 868	805	*298	Horizontal.
60.180	B6203	22	33°40.5'	132°00.0'			14 Mar. 1962	1140	1425	5, 124	604	*423	Do.
60.180	H6204	51	33°38.0'	131°54.0'			30 Mar. 1962	1300	1650	4, 826	4, 026	*419	Do.
60.200a	B6203	23	32°56.8'	133°26.8'			15 Mar. 1962	0050	0400	4, 941	604	*423	Oblique.
60.200b	B6203	24	32°56.8'	133°26.8'			15 Mar. 1962	0400	0520	4, 941	92	*31	Do.
60.200	H6204	52	32°55.0'	133°28.0'			31 Mar. 1962	0255	0425	5, 051	805	*298	Horizontal.
65.54	C6208	105	37°05.0'	122°34.0'	36°59.0'	122°32.5'	15 Aug. 1962	0044	0145	110-275	92	24	Do.
66.50a	C6208	102	36°57.0'	122°10.5'	36°55.5'	122°07.0'	11 Aug. 1962	0044	0144	55	47	24	Do.
66.50b	C6208	103	36°58.0'	122°09.8'	36°57.0'	122°07.0'	11 Aug. 1962	0330	0430	31	47	24	Do.
66.100	C6208	97	35°29.0'	125°51.2'	35°23.0'	125°52.4'	8-9 Aug. 1962	2325	0125	4, 575	183	*46	Do.
68.50	C6208	104	36°43.0'	121°58.5'	36°42.0'	121°58.0'	13 Aug. 1962	0841	0912	183-92	366	*92	Do.
70.51	C6208	106	36°10.5'	121°48.0'	36°08.0'	121°47.0'	15 Aug. 1962	1432	1532	238-677	686	201	Do.
70.60	C6208	101	35°14.0'	123°52.0'	35°07.5'	123°58.5'	9-10 Aug. 1962	2312	0112	4, 118	1, 052	*366	Oblique.
70.80a	B6203	17	35°13.5'	123°47.6'			6 Mar. 1962	1930	2300	4, 026	604	*256	Do.
70.80b	B6203	18	35°13.5'	123°47.6'			6 Mar. 1962	2300	2400	4, 026	121	*29	Horizontal.
70.80-5n	B6203	19	35°18.0'	123°44.0'			7 Mar. 1962	0040	0235	4, 026	92	*9	Do.
70.80	C6208	100	35°14.0'	123°52.0'	35°07.5'	123°58.5'	9-10 Aug. 1962	2312	0112	4, 118	47	24	Do.
70.90	B6203	16	34°53.0'	124°30.0'			6 Mar. 1962	1050	1455	4, 209	604	*256	Oblique.
70.90	C6208	99	34°53.0'	124°33.0'	34°47.0'	124°31.0'	9 Aug. 1962	1520	1720	4, 209	47	24	Horizontal.
70.100	C6208	98	34°34.0'	125°15.0'	34°30.0'	125°12.0'	9 Aug. 1962	0810	1020	4, 667	1, 052	*366	Oblique.
70.130	B6203	15	33°39.0'	127°00.0'			5 Mar. 1962	1200	1520	3, 660	604	*423	Do.
70.200	H6204	53	31°15.0'	132°07.8'			31 Mar. 1962	1905	2330	4, 694	4, 529	*1, 676	Horizontal.

TABLE 1.—Pelagic survey station data—Continued

Station	Vessel and cruise	Se- quence occu- pied	Location of haul				Date	Time of tow (P.s.t.)		Depth of bottom	Tow- ing wire out	Depth fished	Type of haul	
			Start		End			Start	End					
			Lat. N.	Long. W.	Lat. N.	Long. W.								
73.200	B6203	25	30°38.0'	131°53.2'			15-16 Mar. 1962	Hour 2310	Hour 0210	M. 4,758	M. 604	M. 423	Do.	
77.51	C6208	107	35°01.5'	121°00.0'	34°59.4'	120°59.3'	16 Aug. 1962	0033	0133	348-366	110	*13	Do.	
79.54	B6303	163	34°32.0'	120°50.5'	34°30.5'	120°53.2'	1 Mar. 1963	1513	1640		503	*386	Oblique.	
80.51	B6203	6	34°26.5'	120°32.8'			2 Mar. 1962	1750	2110		119	*92	Do.	
80.52	C6208	112	34°22.3'	120°44.0'	34°18.0'	120°43.5'	20 Aug. 1962	0227	0447	458-686		*24	Horizontal.	
80.52	C6303	164	34°31.8'	120°40.2'	34°29.4'	120°37.7'	1 Mar. 1963	1800	1955		77-81	*27	Do.	
80.55	H6204	26	34°18.6'	120°48.0'			16 Mar. 1962	1927	2135		695	*805	Do.	
80.60	B6203	7	34°10.0'	121°09.7'			2-3 Mar. 1962	2340	0235		2,196	377	*264	Oblique.
80.60	H6204	28	34°06.6'	121°08.0'			17 Mar. 1962	0100	0236		2,196	805	*298	Horizontal.
80.60	C6208	113	34°09.5'	121°11.0'	34°05.8'	121°08.0'	20 Aug. 1962	0850	1110		2,196	1,052	*366	Oblique.
80.60	C6303	165	34°11.1'	121°10.0'	34°06.1'	121°04.4'	4 Mar. 1963	1550	1830		1,501	648	*201	Horizontal.
80.65	B6303	166	33°59.0'	121°30.5'	33°53.2'	121°27.7'	4 Mar. 1963	2011	2140		3,294	150	*55	Oblique.
80.70	B6203	8	33°49.2'	121°51.8'			3 Mar. 1962	0830	0935		3,660	377	*264	Do.
80.70	H6204	29	33°54.0'	121°50.0'			17 Mar. 1962	0948	1424		4,260	5,032	*1,863	Horizontal.
80.70	C6208	114	33°48.7'	121°51.0'	33°42.5'	121°49.7'	20 Aug. 1962	1600	1813		3,660	1,052	*366	Oblique.
80.70	C6303	167	33°40.0'	121°54.4'	33°44.0'	121°49.7'	4-5 Mar. 1963	2302	0125		3,569	64	22	Horizontal.
80.75	B6303	168	33°39.0'	122°11.5'	33°34.7'	122°29.0'	5 Mar. 1963	0445	0725		3,660			Oblique.
80.80	B6203	9	33°28.7'	122°32.6'			3 Mar. 1962	1405	1635		3,660	377	*264	Do.
80.80	H6204	30	33°33.0'	122°35.0'			17 Mar. 1962	2045	2230		4,209	805	*298	Horizontal.
80.80	C6208	115	33°26.0'	122°30.0'	33°21.0'	122°29.0'	20-21 Aug. 1962	2320	0120		4,392	24	24	Do.
80.80	C6303	169	33°30.0'	122°38.0'	33°22.3'	122°38.2'	5 Mar. 1963	0605	0850		4,026	640	*183	Do.
80.90	B6203	10	33°09.0'	123°14.0'			3 Mar. 1962	2030	2200		4,392	377	*264	Oblique.
80.90-5n	B6203	11	33°07.0'	123°15.0'			3 Mar. 1962	2300	2400		4,392	92	*9	Horizontal.
80.90	H6204	32	33°13.1'	123°16.0'			18 Mar. 1962	0500	1050		4,172	6,039	*2,234	Do.
80.100	B6203	12	32°49.0'	123°55.0'			4 Mar. 1962	0330	0635		3,660	377	*264	Oblique.
80.100	H6204	33	32°57.0'	123°56.0'			18 Mar. 1962	1512	1654		3,935	805	*298	Horizontal.
80.110	B6203	13	32°28.3'	124°36.2'			4 Mar. 1962	0930	1150		4,392	377	*264	Oblique.
80.120	B6203	14	32°08.7'	125°17.8'			4 Mar. 1962	1630	1915		4,209	377	*264	Do.
80.130	C6208	116	31°55.0'	126°06.0'	31°50.0'	126°07.5'	22 Aug. 1962	0600	0700		4,392	128	24	Horizontal.
80.140	C6208	117	31°26.0'	126°39.0'	31°24.0'	126°40.0'	22 Aug. 1962	1110	1245		4,392	1,200	*403	Oblique.
80.150	C6208	118	31°10.0'	127°17.5'	31°06.0'	127°18.0'	22 Aug. 1962	1750	1925		4,392	1,200	*403	Do.
80.160	C6208	119	30°50.0'	127°57.0'	30°47.0'	127°55.0'	22-23 Aug. 1962	2250	0050		4,026	24	24	Horizontal.
80.170	C6208	120	30°30.0'	128°36.0'	30°27.0'	128°38.0'	23 Aug. 1962	0652	0825		4,392	1,200	*403	Oblique.
80.180	C6208	121	30°07.0'	129°16.0'	30°05.0'	129°19.0'	23 Aug. 1962	1135	1315		4,392	1,200	*403	Do.
80.190	C6208	122	29°49.0'	129°55.0'	29°46.0'	129°54.0'	23 Aug. 1962	1835	1935		4,392	24	24	Horizontal.
80.200	H6204	54	29°29.0'	130°36.0'			1 Apr. 1962	1358	1535		4,502	805	*298	Do.
80.210	C6208	123	29°29.0'	130°36.0'	29°26.0'	130°34.0'	23-24 Aug. 1962	2350	0140		4,392	1,200	*403	Oblique.
82.41	C6208	108	34°18.0'	119°55.0'	34°18.0'	119°53.0'	16 Aug. 1962	1951	2051		458	18	18	Horizontal.
82.61	C6303	191	33°26.3'	121°27.1'	33°23.8'	121°24.0'	13 Mar. 1963	1947	2140		3,660	549	*165	Do.
83.70	C6303	183	33°12.0'	121°26.7'	33°08.5'	121°26.0'	8 Mar. 1963	1810	2130		4,026	686	*183	Do.
83.70a	B6303	184	33°18.0'	121°32.0'	33°13.5'	121°27.5'	8 Mar. 1963	1933	2064		4,026	300	*113	Do.
83.70b	B6303	185	33°12.5'	121°27.5'	33°11.5'	121°25.2'	8 Mar. 1963	2058	2215		4,026	80	18	Do.
83.70c	B6303	186	33°11.5'	121°25.2'	33°09.0'	121°20.2'	8-9 Mar. 1963	2219	0020		4,026	400	*168	Do.
83.72	B6303	188	33°10.7'	121°30.0'	33°04.8'	121°25.0'	9 Mar. 1963	0850	1115		3,660	600	*201	Do.
83.77	C6303	172	33°04.0'	121°58.8'	32°58.0'	121°55.5'	6 Mar. 1963	0800	1015		3,843	1,464	*489	Do.
83.90	C6303	170	32°37.7'	122°47.2'	32°31.4'	122°49.3'	5 Mar. 1963	1400	1700		3,843	1,144	*366	Do.
84.67	C6303	192	33°12.8'	121°11.0'	33°09.5'	121°08.2'	13 Mar. 1963	1517	1710		3,294	961	*238	Oblique.
84.68	C6303	191	33°12.3'	121°12.0'	33°09.3'	121°09.5'	13 Mar. 1963	1243	1420		3,477	824	*247	Horizontal.
84.70	C6303	187	33°06.5'	121°21.5'	33°00.0'	121°19.0'	8-9 Mar. 1963	2350	0300		4,026	824	*220	Do.
84.71	C6303	182	33°09.0'	121°28.0'	33°05.0'	121°26.5'	8 Mar. 1963	1310	1530		4,026	1,098	*311	Oblique.
84.92	B6303	171	32°19.0'	122°52.0'	32°14.0'	122°48.0'	6 Mar. 1963	0305	0525		3,660	700	*311	Do.
85.68	C6303	189	33°05.0'	122°12.0'	33°03.0'	121°07.0'	9 Mar. 1963	1410	1630		2,562	869	*238	Horizontal.
86.92	C6303	175	32°07.3'	122°39.5'	32°00.5'	122°41.4'	6 Mar. 1963	1617	1945		4,209	1,738	*640	Do.
87.70a	B6303	162	32°29.3'	121°09.0'	32°32.0'	121°04.0'	28 Feb. 1963	0645	0845		3,843	650	*274	Oblique.
87.70b	B6303	194	33°14.0'	121°22.0'			18 Mar. 1963	0825	1540		3,843	800		Do.
87.80	C6303	181	32°17.0'	121°44.0'	32°20.8'	121°45.5'	8 Mar. 1963	0525	0755		3,843	1,738	*640	Horizontal.
87.90	C6303	176	31°40.5'	122°03.5'	31°37.0'	122°04.3'	6-7 Mar. 1963	2238	0020		4,026	64	16	Do.
87.200	B6203	27	28°20.0'	130°22.0'			16-17 Mar. 1962	2035	0100		4,758	604	*423	Oblique.
88.105a	B6303	173	31°06.0'	123°12.2'	31°04.6'	123°07.5'	6 Mar. 1963	1313	1525		4,026	800	*311	Do.
88.105b	B6303	174	31°04.6'	123°07.5'	31°03.0'	123°02.0'	6 Mar. 1963	1537	1756		4,026	800	*320	Horizontal.
90.32	B6203	38	33°20.2'	118°05.3'			22 Mar. 1962	0953	1501		769-549	800	*622	Oblique.
90.32	H6204	65	33°19.0'	118°02.7'			6-7 Apr. 1962	2320	0215		787	800	*298	Horizontal.
90.35	B6203	37	33°21.0'	118°18.3'			22 Mar. 1962	0345	0440		86	190	86	Do.
90.45a	H6105	4	32°45.0'	118°48.6'	33°00.1'	119°05.2'	27-28 May 1961	2335	0505	1,391-1,684	1,812	1,093		Do.
90.45b	H6105	5	33°00.9'	119°08.3'	32°48.1'	118°44.1'	28 May 1961	0535	1015		1,510	30	18	Do.
90.45	H6204	63	32°55.5'	118°54.5'			6 Apr. 1962	1605	1735		1,720	800	*298	Do.
90.47	C6208	110	32°49.0'	119°08.0'	32°46.5'	118°57.0'	17 Aug. 1962	1507	1807	1,007-1,373	1,052	366	Oblique.	
90.48a	H6105	1	32°49.6'	119°05.7'	32°53.4'	119°09.5'	27 May 1961	1055	1400		842	1,006	*704	Horizontal.
90.48b	H6105	2	32°46.0'	119°05.4'	32°51.4'	119°10.7'	27 May 1961	1500	1720		842	251	178	Do.
90.48c	H6105	3	32°44.4'	119°05.1'	32°49.0'	119°10.0'	27 May 1961	1845	2100		641	49	18	Do.
90.49a	C6208	109	32°46.0'	119°12.0'	32°44.0'	119°09.0'	17 Aug. 1962			183-55		18	Do.	
90.49b	C6208	111	32°42°											

TABLE 1.—Pelagic survey station data—Continued

Station	Vessel and cruise	Se- quence occu- pied	Location of haul				Date	Time of tow (P.s.t.)		Depth of bottom	Tow- ing wire out	Depth fished	Type of haul
			Start		End			Start	End				
			Lat. N.	Long. W.	Lat. N.	Long. W.							
90.160	C6208	127	29°05.0'	126°38.0'	29°03.0'	126°42.0'	25 Aug. 1962	Hour	Hour	M.	M.	M.	Oblique.
90.180	B6203	31	28°25.0'	127°58.0'			18 Mar. 1962	0200	0200	4,301	1,200	*403	Horizontal.
90.180	H6204	56	28°22.0'	128°00.0'			2 Apr. 1962	1900	2040	4,026	600	*423	Do.
90.180	C6208	126	28°26.0'	127°57.0'	28°23.0'	128°00.0'	25 Aug. 1962	0600	0740	4,484	800	*298	Do.
90.190	C6208	125	28°06.5'	128°33.0'	28°03.5'	128°40.0'	24-25 Aug. 1962	2225	0025	4,392	1,200	*403	Oblique.
90.200	H6204	55	27°46.0'	129°14.9'			2 Apr. 1962	0534	1006	4,392		24	Horizontal.
90.200	C6208	124	27°46.0'	129°14.0'	27°43.0'	129°16.0'	24 Aug. 1962	1525	1705	4,209	4,530	1,676	Do.
91.39a	C6208	146	32°53.3'	118°23.8'	32°32.8'	118°23.0'	5 Sept. 1962	2037	2120	4,392	1,200	*403	Oblique.
91.39b	C6208	147	32°52.9'	118°24.0'	32°51.8'	118°22.0'	6 Sept. 1962	0015	0134	732		36	Horizontal.
91.39c	C6208	148	32°51.7'	118°22.5'	32°51.5'	118°22.0'	6 Sept. 1962	1005	1030	366			Do.
92.28	C6208	150	32°59.5'	117°24.0'	33°03.0'	117°24.5'	6 Sept. 1962	2256	2356	458			Surface
92.115	B6303	177	30°18.8'	123°27.3'	30°12.0'	123°24.0'	7 Mar. 1963	0030	0255	4,026	250	*73	Do.
93.26	C6208	141	33°03.5'	117°19.2'	33°01.5'	117°18.0'	3 Sept. 1962	2017	2130	37-55		36	Do.
93.28	C6208	142	32°58.5'	117°23.0'	33°00.5'	117°24.0'	3-4 Sept. 1962	2315	0015	549			Surface
93.29	C6208	140	32°53.5'	117°25.0'	32°53.5'	117°27.0'	3 Sept. 1962	0840	1215	549	915	201	Do.
93.31	C6303	190	32°51.1'	117°35.8'	32°49.2'	117°32.3'	12 Mar. 1963	1305	1510	732	915	*274	Do.
93.100	C6303	179	30°31.2'	122°15.7'	30°26.2'	122°09.8'	7 Mar. 1963	1215	1450	4,026	549	*105	Do.
94.28a	C6208	139	32°49.5'	117°20.0'	32°47.5'	117°20.5'	2 Sept. 1962	0115	0215	82		73	Do.
94.28b	C6208	143	32°50.5'	117°20.0'	32°48.0'	117°19.5'	4 Sept. 1962	0230	0400	66			Surface
94.29a	C6208	135	32°47.0'	117°19.5'	32°45.5'	117°19.0'	31 Aug. 1962	1142	1310	366		296	Do.
94.29b	C6208	136	32°44.0'	117°18.0'	32°46.0'	117°18.5'	1 Sept. 1962	0745	0943	73		*9	Do.
94.29c	C6208	137	32°46.5'	117°18.5'	32°45.0'	117°19.7'	1 Sept. 1962	1913	2022	73-146		*82	Do.
94.29d	C6208	149	32°43.5'	117°17.5'	32°42.0'	117°17.5'	6 Sept. 1962	1715	1820	55			Surface
94.29e	C6208	151	32°47.0'	117°19.0'	32°44.0'	117°18.0'	7 Sept. 1962	0142		55			Surface
94.30	C6208	144	32°39.0'	117°24.5'	32°38.0'	117°22.5'	4 Sept. 1962	2025	2131	275		183	Do.
94.32a	B6204	67	32°33.0'	117°27.5'	32°35.4'	117°30.8'	7 Apr. 1962	0218	0350	92	92	*37	Do.
94.32b	B6204	68	32°35.4'	117°30.8'	32°38.6'	117°33.3'	7 Apr. 1962	0400	0545	92	92	*37	Do.
95.30	C6208	145	32°37.0'	117°23.0'	32°35.0'	117°21.5'	4 Sept. 1962	2025	2131	275			Surface
95.31a	B6204	62	32°29.0'	117°21.5'	32°30.6'	117°23.1'	6 Apr. 1962	1320	1422	549-641	400	*282	Do.
95.31b	B6204	64	32°29.0'	117°21.6'	32°30.7'	117°24.5'	6-7 Apr. 1962	2305	0025	961	800	*563	Oblique.
95.31c	B6204	66	32°31.4'	117°21.6'	32°30.7'	117°24.5'	7 Apr. 1962	0043	0207	137	92	*37	Horizontal.
95.31d	B6204	69	32°30.7'	117°23.4'	32°32.2'	117°25.5'	7 Apr. 1962	1434	1625	686-1098	800	*563	Do.
97.40	C6303	197	31°49.0'	117°53.0'	31°45.2'	117°46.7'	21 Mar. 1963	1822	2115	421-439	732	*274	Oblique.
97.50	B6203	40	31°35.0'	118°30.7'			27 Mar. 1962	0140	0415	2,196	600	*423	Horizontal.
97.65	C6303	195	31°00.0'	119°32.0'	30°54.7'	119°28.4'	19 Mar. 1963	0858	1245	3,477	1,372	*458	Do.
99.31	C6208	138	31°54.4'	116°59.0'	31°51.5'	116°57.5'	1-2 Aug. 1962	2245	0020	732		66	Do.
100.40	H6204	70	31°21.2'	117°26.7'			12 Apr. 1962	0229	0414	1,874	800	*298	Do.
100.40	C6303	198	31°21.0'	117°27.0'	31°18.0'	117°27.3'	22 Mar. 1963	0450	0620	1,995	92	*22	Do.
100.50	H6204	71	31°00.0'	118°09.9'			12 Apr. 1962	1020	1155	1,739	800	*298	Do.
100.60	H6204	72	30°39.0'	118°45.5'			12-13 Apr. 1962	2120	0205	2,782	4,530	*1,676	Do.
100.65	C6303	196	30°32.5'	119°09.8'	30°26.4'	119°06.2'	19 Mar. 1963	1530	1930	3,111	1,372	*458	Do.
100.80	H6204	73	29°58.5'	120°07.0'			13 Apr. 1962	1630	2100	3,962	4,530	*1,676	Do.
100.90	H6204	74	29°38.0'	120°46.8'			14 Apr. 1962	0048	0305	3,861	800	*298	Do.
100.100	H6204	75	29°19.0'	121°25.0'			14 Apr. 1962	0941	1347	3,843	4,530	*1,676	Do.
100.120	H6204	76	28°40.5'	122°46.8'			14 Apr. 1962	2230		4,099	800	*298	Do.
100.140	H6204	77	27°59.4'	124°05.8'			15 Apr. 1962	1008	1416	4,209	4,530	*1,676	Do.
100.160	H6204	78	27°22.6'	125°20.0'			6 Apr. 1962	0306	0724	4,145	4,530	*1,676	Do.
103.50	C6303	199	30°18.4'	117°47.0'	30°05.5'	117°45.2'	22 Mar. 1963	1300	1830	2,837	824	220	Do.
107.60	C6303	200	29°30.0'	118°00.0'	29°21.0'	118°00.0'	22-23 Mar. 1963	2230	0200	3,569	46	9	Do.
108.63	C6303	201	29°12.1'	118°09.0'	29°13.8'	118°03.5'	23 Mar. 1963	0328	0620	1,830	1,372	*458	Do.
110.35	H6204	84	29°46.5'	115°58.5'			21 Apr. 1962	0200	0400	1,153	800	*298	Do.
110.35	C6303	203	29°46.3'	116°01.2'	29°42.8'	115°59.0'	23 Mar. 1963	2100	2315	1,153	732	*201	Do.
110.36	C6303	204	29°41.2'	116°41.2'	29°36.2'	115°59.0'	24 Mar. 1963	1225	1624	1,830	1,190	*403	Do.
110.40	H6204	83	29°32.4'	116°15.1'			20 Apr. 1962	2120	2300	2,416	800	*298	Do.
110.46	C6303	202	29°28.4'	116°47.0'	29°25.8'	116°45.0'	23 Mar. 1963	1412	1600	1,830	640	*156	Do.
110.50	B6203	44	29°16.5'	116°59.0'			28 Mar. 1962	0100	0330	3,660	600	*423	Do.
110.100	H6204	82	27°32.1'	120°14.0'			19 Apr. 1962	0520	0700	3,953	800	*298	Do.
110.120	H6204	81	26°56.8'	121°32.4'			18 Apr. 1962	1644	2057	4,269	4,530	*1,676	Do.
110.140	H6204	80	26°16.0'	122°49.2'			18 Apr. 1962	0653	0750	4,108	1,100	*410	Do.
110.160	H6204	79	25°34.7'	124°07.0'			17 Apr. 1962	1530	1930	4,200	4,530	*1,676	Do.
111.36a	C6303	207	29°41.5'	115°59.6'	29°34.7'	115°57.5'	26 Mar. 1963	0200	0550	1,830	686	*165	Do.
111.36b	C6303	208	29°39.1'	116°01.3'	29°32.4'	115°59.0'	26 Mar. 1963	0900	1330	2,196			Do.
111.37a	C6303	205	29°34.7'	116°00.0'	29°32.0'	115°59.0'	25 Mar. 1963	0912	1255	2,196	1,372	*366	Oblique.
111.37b	C6303	206	29°38.9'	116°01.8'	29°31.0'	116°00.4'	25 Mar. 1963	1425	1900	2,196	1,372	*403	Do.
113.34a	C6303	209	29°13.0'	115°30.7'	29°10.8'	115°28.5'	26 Mar. 1963	1700	1840	220	640	150	Horizontal.
113.34b	C6303	210	29°21.0'	115°38.0'	29°14.5'	115°32.4'	27 Mar. 1963	1040	1435	549	686	*192	Oblique.
118.43	B6212	152	28°11.0'	115°41.6'	28°08.0'	115°40.5'	1 Dec. 1962	1257	1434	586	657	*306	Horizontal.
120.45	H6204	85	27°43.2'	115°32.3'			22 Apr. 1962	1634	1813	3,294	800	*298	Do.
120.45	B6212	153	27°44.0'	115°33.0'	27°38.7'	115°30.2'	1 Dec. 1962	1724	1922	2,196	600	*311	Do.
120.50	H6204	86	27°29.1'	115°51.5'			22-23 Apr. 1962	2305	0328	3,916	4,530	*1,676	Do.
120.60	H6204	87	27°00.0'	116°36.3'			23 Apr. 1962	0850	1023	3,660	800	*298	Do.
120.70	H6204	88	26°51.0'	117°09.2'			23 Apr. 1962	1640	2042	3,660	4,530	*1,676	Do.
120.80	H6204	89	26°31.0'	117°47.0'			24 Apr. 1962	0044	0223	3,861	800	*298	Do.
120.90	H6204	90	26°09.0'	118°26.2'			24 Apr. 1962	0715	1135	4,063	4,530	*1,676	Do

Cruise B6212: R/V *Black Douglas*; December 1-3, 1962; central to southern Baja California, to about 80 km. (50 miles) seaward; 10 tows with CMWBT: 55-176 (4), 240-311 (3), 386-426 (3); other work, collections at Marquis Point and Magdalena and Santa Maria Bays, Baja California, using seines, rotenone, otter trawls, and dip nets.

Cruise B6303: R/V *Black Douglas*; February 28 to March 18, 1963; Point Conception to off San Diego, Calif., to about 480 km. (300 miles) seaward; 13 tows with CMWBT: 18-73 (3), 113-201 (3), 274-386 (5), unknown (2); negative tows, stations 87.70a, 87.70b; other work, oblique and horizontal tows with 1-m. standard plankton net

and 1-m. closing net and bottom trawling with 16-ft. otter trawl.

Cruise C6303: R/V *John N. Cobb*; March 1-27, 1963; Point Conception, Calif. to central Baja California, to about 430 km. (270 miles) seaward; 36 tows with *Cobb* pelagic trawl Mark II: 9-27 (5), 82-192 (10), 201-403 (15), 458-489 (4), 640 (2); negative tows, stations 80.70, 85.68, 111.36b.

STATION DATA

The basic station numbering system in use since 1950 for the California Cooperative Oceanic Fisheries Investigations (CalCOFI) was used for station designation during the pelagic survey (fig. 1). An explanation of this numbering plan was



FIGURE 1.—CalCOFI basic station plan since 1950.

given by Scripps Institution of Oceanography and Fish and Wildlife Service (1952). The stations occupied during the eight cruises are shown in figures 2A and 2B.

The station data for the cruises are given in table 1. An asterisk in the table indicates an approximate value. The stations are listed in increasing numerical order by line from north to south and by station number from east to west. When the same station was occupied more than once during a cruise, the earliest occupancy was designated "a", the next "b", . . . The depth fished was determined or estimated in a variety of ways. A depth telemeter with a conducting cable was used for some stations on cruise C6208; the Brown Depth Recorder for several stations on cruises H6105 and H6204; and a bathykymograph for a few stations on cruises B6203, B6204, B6212, and B6303. For some stations on cruise H6204, a factor of 0.37 times the length of the wire out, was used to estimate the depth fished.

The depth of bottom at each station, the amount of wire out, and the depth fished are recorded in meters. This has produced some uneven or ir-

regular numbers that are frequently repeated in table 1. One reason for this is that depth of bottom at each station was originally recorded in fathoms, either from the depth recorder or chart reading, and was subsequently converted to meters to conform to the required style of this report. At a number of stations on some of the cruises, the amount of wire out was set at a particular number of meters, and the calculated or estimated fishing depth was a reflection of amount of wire out (for example, on cruise H6204 most stations were made with either 800 or 4,500 m. of wire out, and the estimated depth of fishing was 298 and 1,676 m., respectively).

The types of tows are listed as horizontal or oblique. For horizontal tows, a selected amount of wire was let out and the trawl was towed within a generally restricted depth range. Obviously, the trawl was fishing in descent to and ascent from this depth, but most of the fishing effort for a horizontal tow was usually near the maximum depth fished. It is recognized that after the selected amount of wire has been let out, the trawl may sink for a time while being towed. Also, if



FIGURE 2.—(A) Stations occupied during pelagic survey, (B) Stations occupied in the central and shoreward portion of the pelagic survey.

the ship's speed is reduced when the wire retrieval begins, the trawl may sink and continue fishing deeper than the calculated maximum depth recorded for the horizontal tow. The oblique tows were made in two ways: (1) by letting out a selected length of wire as fast as feasible and retrieving slowly or in stages (as, on a deep tow, taking in 100 m. of wire during about 3 to 5 minutes and towing for 10 minutes before retrieving more wire) and (2) by letting the wire out slowly or in stages and retrieving as fast as possible.

COLLAPSIBLE MIDWATER BEAM TRAWL

On vessels such as the *Black Douglas*, inadequately equipped to operate (most) large nets, it was necessary to have a collapsible net (fig. 3). Views of operation of the net and certain details of construction and the jury-rigged winch and H-frame aboard the *Black Douglas* are shown in figures 4 and 5.

In devising the CMWBT, several features desirable in operating such a net were considered, and attempts were made to incorporate these features into the design and function.

Mouth opening.—This should be large to sample a relatively large area and to reduce escapement.

The horizontal opening was fixed at 10 feet by the top and bottom beams. The vertical, nonrigid opening was hung at 14 feet. In towing, the vertical opening was reduced to about 12 feet at 2 knots and to about 10 feet at 4 knots; the latter still left a sampling area of about 100 square feet.

Towing speed.—The CMWBT was strongly constructed. The maximum speed at which it was towed was about 5 knots, but faster speeds could have been used.

Mouth opening obstruction.—There was no obstruction from the top beam bridle, and that from the bottom beam bridle was not great; this could be eliminated by a spreader bar.

Specimen damage.—This was reduced by a specially constructed cod end (figs. 3 and 5D).

The bullet-shaped device attached to the top beam in figure 4 is a bathykymograph. This model functioned sporadically and unsatisfactorily in our experiments.

SUMMARY OF FISHES COLLECTED

More than 189 species of fishes were taken in the survey. The exact number cannot be determined at this time because of the uncertain identification of more than 18 forms. At least one previous-

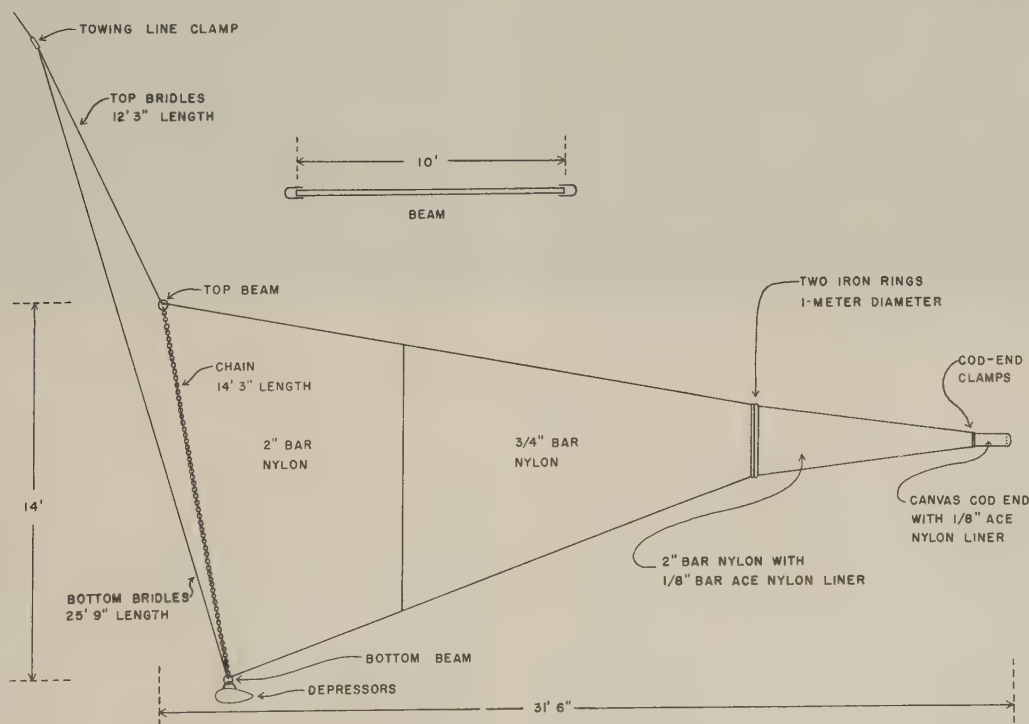


FIGURE 3.—Diagram (lateral view) of 10- by 14-ft. collapsible midwater beam trawl (CMWBT).



FIGURE 4.—CMWBT. A, emerging. B, boarding. C, top beam secured to H-frame, hauling in bottom beam. D, both beams secured. Cylinder attached to middle of top beam is bathythermograph.

ly unnamed and undescribed genus and at least four undescribed species were taken; these specimens have been made available to specialists working on the groups concerned. Sixteen orders of fish and 71 families are represented, including 52 species of the order Isospondyli, 51 species of Iniomi, and 37 of Percomorphi. The greatest number of species in a single family was 40 in the Myctophidae. The greatest number of species in a single genus was 12 in *Lampanyctus* (Myctophidae); the next greatest was 8 in *Melamphaes* (Melamphaidae).

About 52,000 fish were taken in the pelagic survey. The order Isospondyli comprised about 56 percent of this total, including the numerically most abundant species, *Engraulis mordax*, which itself was 34 percent of the total number. The Iniomi was the second most abundant order, about 38 percent of the total; the family Myctophidae comprised most of this percentage. The myctophid genus *Lampanyctus* (including the subgenus *Triphoturus*), was 21 percent of the total, and *Lampanyctus* (*Triphoturus*) *mexicanus* was the second most abundant species—about 18 percent

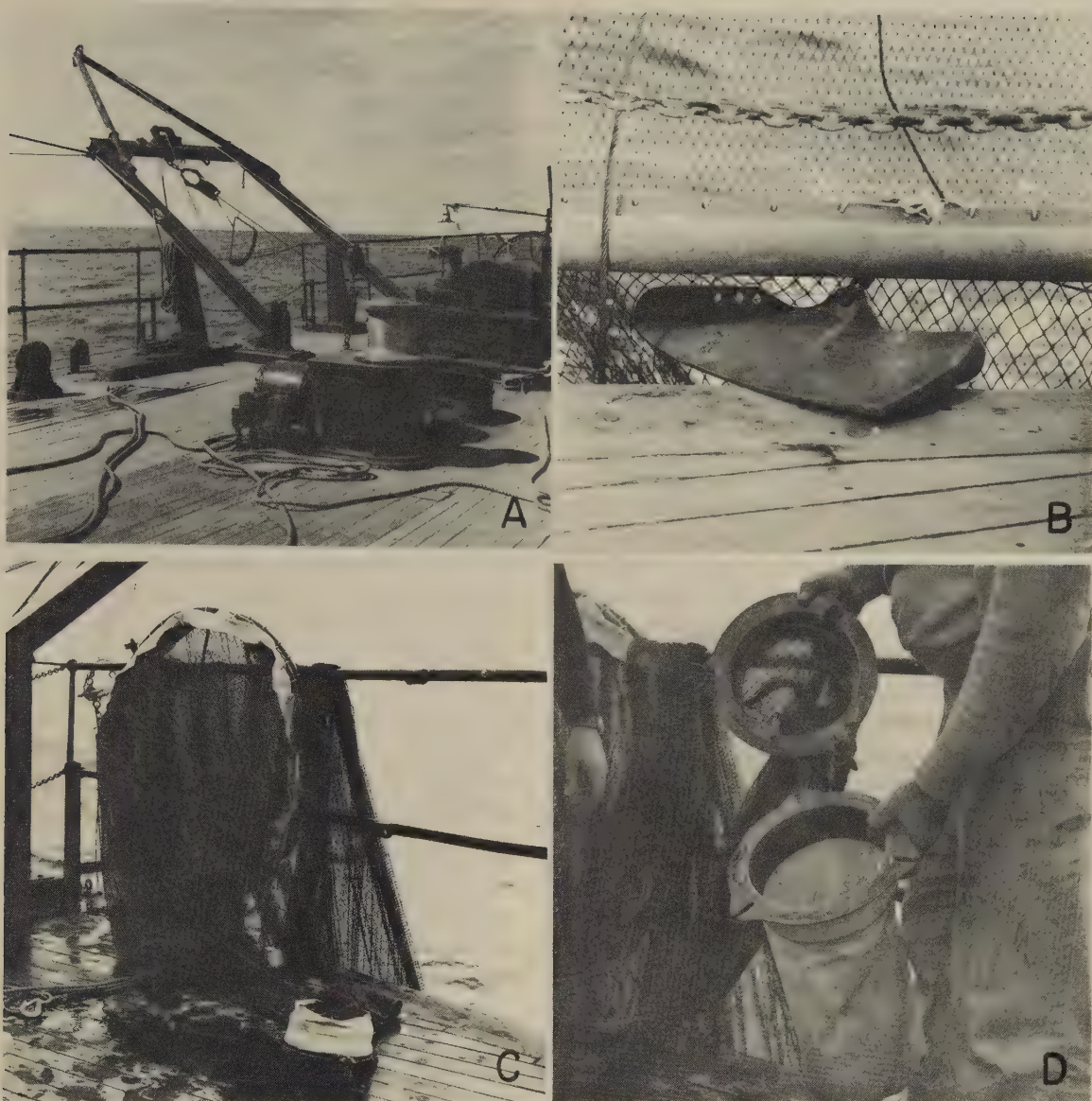


FIGURE 5.—CMWBT. A, towing; note H-frame, slush block, angle indicator, meter wheel, winch, and capstan. B, depressor and rib on back of bottom beam for lashing net. C, afterpart of net with two detachable one-meter rings. D, lined cod end and cod-end clamp.

of the total. Forty-four of the species were represented by a single specimen. The preponderance of anchovies (*Engraulis mordax*) in the above figures does not indicate a high relative abundance of this species over the survey area—as is true for *Lampanyctus* (*T.*) *mexicanus*—because the bulk of the anchovies taken on the survey was from two large catches at stations close to shore.

During the survey, 198 tows caught one or more fish (12 other tows did not catch fish, for various reasons). Species of Myctophidae were taken at

more of the “successful stations” than any other family. *Lampanyctus* (*T.*) *mexicanus* was taken at 76 stations—more than any other species. Other myctophids caught at a relatively large number of stations were: *Heirops crockeri* and *Ceratoscopelus townsendi* (66 stations each), *Lampanyctus ritteri* (63 stations), *Diaphus theta* (61), *Symbolophorus californiense* (55), and *Stenobrachius leucopsarus* (54). Of the Gonostomatidae, *Cyclothone signata* was taken at 64 stations, *Cyclothone acclinidens* at 49, and *Danaphos oculatus* at 47.

Three species of Sternoptychidae were captured at a large number of stations—*Argyropelecus hawaiiensis* at 54, *A. pacificus* at 49, and *A. intermedius* at 45. Three other species collected at a number of stations were *Idiacanthus antrostomus* and *Scopelogadus mizolepis bispinosus* (50 each) and *Merluccius productus* (42). Sixty of the species recorded were caught at only one station.

The most abundant species in a single tow was *Engraulis mordax*—about 9,000 specimens (450 pounds) taken at a single station. *Lampanyctus (T.) mexicanus* had the next highest numbers—about 3,000 specimens at one station and 1,857 at another. Other large single collections were *Ceratoscopelus townsendi* (944), *Stenobranchius leucopsarus* (735), *Vinciguerria lucetia* (537), *Merluccius productus* (495), and *Leuroglossus stilbius* (396).

The maximum number of species in a single tow was 44, with the Cobb pelagic trawl on cruise C6303 at station 86.92. On the same cruise, relatively large numbers of species per tow were taken at stations 100.65 (41 species), 83.77 (38), and 87.80 (37). Maximum numbers of species per tow with the 10-ft. Isaacs-Kidd midwater trawl (IKMWT) were taken on cruise H6204 at stations 80.90 (34 species) and 60.60 (32). The maximum number of species per tow with the collapsible net was 21 on cruise B6303 at station 84.92.

Many variables affected the numbers and species of fishes caught on the survey including depth of tow, time of year, diurnal migration, speed and length of tow, size of net, size of net webbing, and water mass sampled. Because of these variables, many of the numbers and percentages just cited relate to the survey rather than to the character of the pelagic environment.

For abundant and for more significant species, the locations of capture are shown on distribution charts. These charts bear one symbol for each station at which a species was caught—they do not indicate the capture of a species more than once at a single station.

The specimens preserved from the pelagic survey have been placed in four collections. Some of the larval and juvenile forms are in the Bureau of Commercial Fisheries California Current Resources Laboratory. A small representative series of the bathypelagic species is in the Stanford Uni-

versity Natural History Museum. A large representative series of most species taken is in the Fish Division of the U.S. National Museum. The remainder of the material, comprising the bulk of the collection and representatives of most species taken, is in the Marine Vertebrate Collection of Scripps Institution of Oceanography. The disposition of all the specimens is recorded in the Field Data Books of the Bureau Laboratory at La Jolla and in the collection records at Scripps Institution of Oceanography. Representative type material of any new taxa that are based on these specimens will be placed in the U.S. National Museum.

ANNOTATED LIST OF FISHES

In preparing the data for this report we attempted, with the help of other ichthyologists, to determine specific identifications of the specimens. Many taxonomic problems were not solved; we briefly describe these in the annotations of the species and also include our resolutions of some of the problems.

The fishes listed below are arranged phylogenetically by order and family. Each record of capture is listed under the species in the following abbreviated form, from left to right: the station of capture; the cruise during which the station was occupied; the number of specimens taken at that station, in parentheses; and the length or length range in millimeters of the specimens. For some collections, numbers or lengths of specimens are not available; for others, weight instead of length is given. At a few stations specimens were discarded at sea before accurate records were made.

Lengths of specimens are given in millimeters of standard length (SL), except where otherwise noted. Total length (TL) is used for a few species, and where this designation is given for the initial entry in a species list, all subsequent measurements in that list are in total length. Specimens 100 mm. in length and larger were measured to the nearest millimeter; most specimens smaller than 100 mm. were measured either to the nearest millimeter, or to the nearest half-millimeter. In collections with damaged specimens that were not measured, "dis." (disintegrated) is used instead of a length. A plus sign following the length measurement of some specimens indicates that a portion of the posterior end of the body was missing.

ELASMOBRANCHII

CARCHARHINIDAE

1. *Prionace glauca* (Linnaeus).

Figure 6A.

60.55, C6208, (4) 865–1,785 mm. TL; 65.54, C6208, (3) 1,255–1,365 mm.; 91.39b, C6208, (1) 568 mm.; 107.60, C6303, (1) 1,200 mm.

MYLIOBATIDAE

2. *Holorhinus californicus* (Gill).

Figure 6A.

93.26, C6208, (3) ca. 5 kg., no length recorded.

TORPEDINIDAE

3. *Torpedo californica* Ayres.

Figure 6A.

77.51, C6208, (1) 453 mm. TL; 80.52, C6208, (1) 422 mm.; 94.28b, C6208, (1) ca. 5 kg.; no length recorded.

This species is generally considered to be a benthic inhabitant of moderately deep water. For the first two records above, however, night tows of the *Cobb* pelagic trawl at the surface (trawl fishing no deeper than 24 m.) captured single specimens of *Torpedo* about 24 km. (15 miles) offshore in water about 350 to 690 m. deep.

ISOSPONDYLI

CLUPEIDAE

4. *Sardinops caerulea* (Girard).

Figure 6B.

94.28b, C6208, (9) 225–275 mm.; 94.29b, C6208, (43) 195–235 mm.; 84.29c, C6208, (2) 195 mm.; 94.30, C6208, (1) 225 mm.

ENGRAULIDAE

5. *Engraulis mordax* Girard.

Figures 6B and 7.

65.54, C6208, (ca. 450) 113–150 mm.; 66.50, C6208, (few) ca. 102 mm.; 70.60, C6208, (1) 33 mm.; 70.80, C6208, (2) 29–30 mm.; 70.90, C6208, (17) 21–27 mm.; 77.51, C6208, (ca. 250) 102–143 mm.; 80.52, C6208, (10) 28.5–143 mm.; 80.60, C6208, (1) 37 mm.; 80.65, B6303, (1) 121 mm.; 80.80, H6204, (1) 141 mm.; 82.45, C6208, "10 lbs. (4 kg.) in all," sample (19) 109–150 mm.; 82.69, C6303, (58) 118–144 mm.; 83.70b, B6303, (25) 120–140 mm.; 83.70c, B6303, (1) 131 mm.; 84.70, C6303, (44) 120–137 mm.; 87.90, C6303, (1) 150 mm.; 90.32, H6204, (3) 108–123 mm.; 90.45, H6105, (13) 4–14 mm.; 90.48b, H6105, (193) 4–28 mm.; 92.28, C6208, (50) ca. 125 mm.; 93.28, C6208, (ca. 100) 2 kg. adults; 93.29, C6208, (200 kg.) 100 fish sample, 85–135 mm.; 94.29b, C6208, (4) ca. 100 mm.; 94.29c, C6208, (16) 55–125 mm.; 95.30, C6208, (1) 150 mm.; 97.40, C6303, (1) 121 mm.; 99.31, C6208, (16) ca. 50 mm.; 107.60, C6303, (2) 123–126 mm.; 110.35, C6303, (6) 116–126 mm.; 113.34b, C6303, (ca. 170 kg.) 115–135 mm.; 120.45, H6204, (2) 16–17.5 mm.; 120.50, H6204, (2) 12.5–14 mm.

Anchovies were taken at 33 stations. Nine of these records were of larvae or small juveniles from close inshore to about 260 km. (160 miles) offshore. Three stations produced records of anchovies that add significantly to our knowledge of the biology of this species. (1) At station 89.90, C6303, one adult was taken about 400 km. (250 miles) from nearest landfall. (2) At station 83.70, B6303, in the San Juan Seamount area—where hake eggs were abundant in routine oblique plankton tows (to about 140 m.), and where freshly spent hake were caught in about 121 and 165 m.—anchovy eggs were abundant in a near-surface plankton tow (about 5.5 m.), and running ripe anchovies were caught in a midwater trawl at about 81 m. The *Cobb* echo sounder showed subsurface concentrations at 73 m. and 146 to 220 m. in this area. These concentrations probably represented anchovies spawning above a deeper school of hake that was spawning or had just finished spawning. (3) At station 93.29, C6208, 13 km. (8 miles) off La Jolla over water about 475 m. (260 fathoms) deep, the *Cobb* Simrad registered a dense concentration at about 201 m. (110 fathoms) (fig. 7). With the aid of the depth telemeter, the trawl was towed through this area. The resulting catch was 200 kg. of anchovies. The Simrad was monitored throughout the tow; and the lack of other concentrations indicated that a dense and unusually deep school of anchovies was sampled. A bathythermograph (BT) cast at this station showed a surface temperature of 68° F., a thermocline at about 18 to 82 m., and a temperature of 74° F. at 201 m.

ALEPOCEPHALIDAE

6. *Alepocephalus tenebrosus* Gilbert ?

Figure 6C.

80.90, H6204, (1) 12.5 mm.; 100.60, H6204, (1) 25 mm.; 100.80, H6204, (1) 28 mm.; badly damaged.

The specific identifications are questionable because of the small size of the specimens.

7. *Talismania bifurcata* (Parr).

Figure 6C.

90.120, H6204, (1) 33 mm.; 110.120, H6204, (1) 47 mm.; 120.50, H6204, (1) 44 mm.

SEARSIDAE

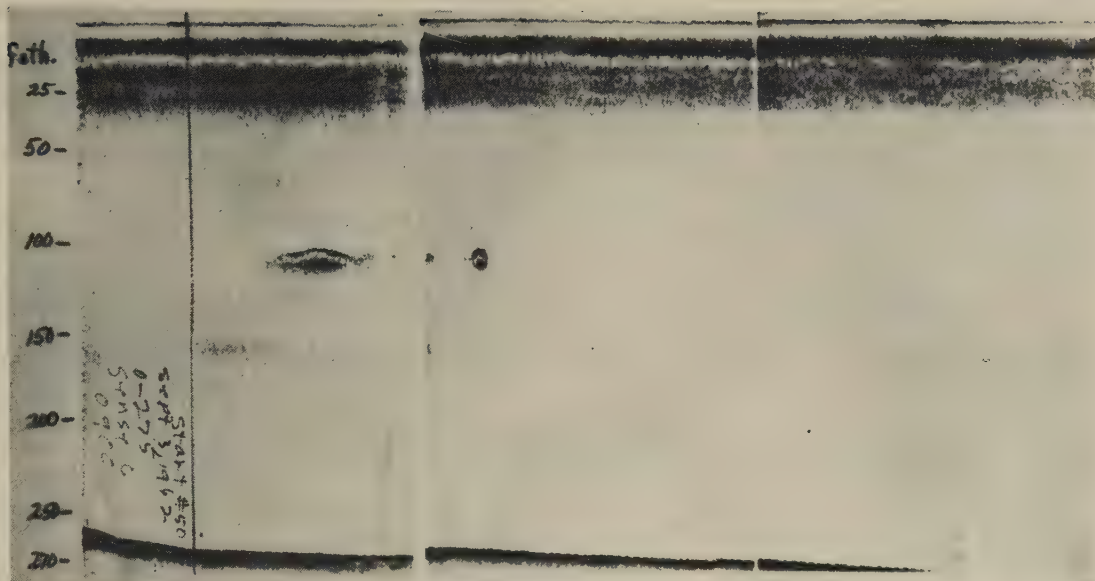
8. *Sagamichthys abei* Parr.

Figure 6C.

60.60, H6204, (2) 25.5–41.5 mm.; 60.80, H6204, (1) 45.5 mm.; 60.80, C6208, (2) 106–139 mm.; 60.90, H6204, (1)



FIGURE 6.—Locations of capture of: A, *Prionace glauca*, *Holorhinus californicus*, *Torpedo californica*. B, *Sardinops caerulea*, *Engraulis mordax*. C, *Alepocephalus tenebrosus?*, *Talismania bifurcata*, *Sagamichthys abei*. D, *Pellisulus facilis*, *Mirorictus taaningi*, *Holtbyrnia macrops?*, *Holtbyrnia sp.*



77 mm.; 60.100, H6204, (1) 24.5 mm.; 80.55, H6204, (1) 63 mm.; 80.70, H6204, (1) 21 mm.; 83.77, C6303, (4) 53.5–116 mm.; 86.92, C6303, (3) 106–215 mm.; 87.80, C6303, (3) 96–147 mm.; 90.48a, H6105, (5) 26–28.5 mm.; 90.70, H6204, (1) 38.5 mm.; 90.70, C6208, (2) 164–171 mm.; 95.31c, B6204, (4) 18–36.5 mm.; 97.50, B6203, (1) 35.5 mm.; 97.65, C6303, (8) 43–223 mm.; 100.40, H6204, (1) 37 mm.; 100.60, H6204, (1) 118 mm.; 100.65, C6303, (28) 63–252 mm.; 100.90, H6204, (1) 90 mm.; 100.100, H6204, (1) 121 mm.; 108.63, C6303, (52) 128–245 mm.; 120.80, H6204, (1) 58.5 mm.; 140.35, B6212, (1) ca. 18 mm.

9. *Pellisulus facilis* Parr.

90.120, H6204 (1) 56.5 mm.

10. *Mirorictus taaningi* Parr.

120.70, H6204, (1) 120 mm.

11. *Holtbyrnia macrops* Maul?

80.90, H6204, (2) 23-64 mm.; 100.140, H6204, (1) 33 mm.

12. *Holtbyrnia* sp.

Figure 6D.

80.100, H6204, (1) 22.5 mm.; 90.45a, H6105, (2) 28–29.5 mm.; 90.48a, H6105, (9) 15–33.5 mm.; 120.90, H6204, (1) 31.5 mm.

These specimens are specifically distinct from those listed above as *Holtbyrnia macrops* Maul ? and may represent an undescribed species (R. J. Lavenberg, personal communication).

ARGENTINIDAE

13. *Nansenia* sp.

90.120, H6204, (1) 10.5 mm.

This specimen was taken about 500 km., south-east of Point Conception, Calif. There appear to be two species of *Nansenia* in the eastern North Pacific—a more northern form described as *N. candida* by Cohen (1958: 53) and a more southern form which is apparently undescribed. The above specimen, because of its small size and the intermediate location of its capture between the known ranges of the two species, cannot now be specifically identified (E. H. Ahlstrom, personal communication). The familial classification of this and the six following genera of argentinoid fishes was proposed by D. M. Cohen (personal communication).

14. *Argentina sialis* Gilbert.

95.31b, B6204, (1) 22.5 mm.

This specimen was taken about 25 km. (15 miles) west of San Diego, Calif.

15. *Microstoma microstoma* (Risso).

83.90, C6303, (1) 115 mm.

This specimen was taken about 275 km. (170 miles) southeast of Point Conception, Calif.

BATHYLAGIDAE

16. *Leuroglossus stilbius* Gilbert.

Figure 8A.

70.80–5N, B6203, (1) 31 mm.; 77.51, C6208, (1) 89 mm.; 80.55, H6204, (5) 33.5–107 mm.; 80.60, H6204, (1) 46 mm.; 80.70, H6204, (1) 32 mm.; 80.90–5N, B6203, (4) 28.5–32 mm.; 80.90, H6204, (3) 30.5–69 mm.; 82.45, C6208, (123) 47–94 mm.; 82.69, C6303, (39) 28–109 mm.; 83.70c, B6303, (2) 61.5–74 mm.; 83.70, C6303, (3) 78–90 mm.; 84.70, C6303, (28) 61–110 mm.; 90.32, H6204, (52) 32–99 mm.; 90.45a, H6105, (99) 22–106 mm.; 90.48a, H6105, (339) 5.5–51 mm.; 90.48b, H6105, (396) 5–23 mm.; 90.48c, H6105, (2) 22–25 mm.; 90.60, H6204, (10) 31–74.5 mm.; 90.70, C6208, (1) 28 mm.; 94.32a, B6204, (19) 29.5–55 mm.; 94.32b, B6204, (25) 25.5–54.5 mm.; 95.31a, B6204, (2) 33–

34.5 mm.; 95.31b, B6204, (14) 32.5–47 mm.; 95.31c, B6204, (18) 31.5–41 mm.; 97.40, C6303, (239) 35–105 mm.; 100.40, H6204, (1) mm.; 100.40, C6303, (1) 92.5 mm.; 100.65, C6303, (1) 18 mm.; 110.35, C6303, (338) 35–109 mm.; 111.36a, C6303, (ca. 50) adults damaged and discarded at sea; 120.45, H6204, (3) 26.5–44 mm.; 123.45, B6212, (1) 23.5 mm.; 133.35, B6212, (4) 33–40 mm.; 140.35, B6212, (1) 28 mm.

17. *Bathylagus ochotensis* Schmidt.

Figures 8A and 9.

60.60, H6204, (3) 18.5–25 mm.; 60.70, H6204, (1) 13.5 mm.; 60.80, H6204, (4) 18–22 mm.; 60.80, C6208, (1) 37.5 mm.; 60.90, H6204, (4) 24–30 mm.; 60.100, H6204, (3) 17–24 mm.; 60.140, H6204, (1) 23 mm.; 70.80b, B6203, (3) 18–22 mm.; 70.80–5N, B6203, (1) 21 mm.; 80.60, H6204, (2) 49–65 mm.; 80.70, H6204, (1) 25 mm.; 80.90–5N, B6203, (12) 48–80 mm.; 80.100, B6203, (1) 77 mm.; 83.69, C6303, (6) 75.5–119 mm.; 84.70, C6303, (2) 64–86 mm.; 86.92, C6303, (1) 55.5 mm.; 90.70, H6204, (1) 29 mm.; 108.63, C6303, (2) 56–66 mm.

This and the other three species of *Bathylagus* captured were identified with a key prepared by D.M. Cohen.

18. *Bathylagus wesethi* Bolin.

Figures 8B and 10.

60.60, H6204, (2) 68–72 mm.; 60.90, H6204, (6) 22–33.5 mm.; 60.100, H6204, (3) 23.5–46 mm.; 60.120, B6203, (3) 36.5–70 mm.; 60.140, H6204, (3) 28.5–38 mm.; 60.160, B6203, (1) 27 mm.; 60.180, H6204, (1) 25.5 mm.; 80.55, H6204, (6) 28.5–33 mm.; 80.60, B6203, (1) 60.5 mm.; 80.70, B6203, (1) 28 mm.; 80.70, H6204, (3) 33–34 mm.; 80.90–5N, B6203, (9) 32–52 mm.; 80.90, H6204, (11) 23.5–78 mm.; 80.100, H6204, (3) all ca. 27 mm.; 82.69, C6303, (12) 25–69 mm.; 83.70a, B6303, (1) 28 mm.; 86.92, C6303, (2) 39.5–47 mm.; 87.80, C6303, (3) 26.5–83.5 mm.; 90.45a, H6105, (22) 33–75 mm.; 90.60, H6204, (1) 27 mm.; 90.70, H6204, (3) 23–75 mm.; 90.120, H6204, (2) 17–23 mm.; 97.40, C6303, (71) 26.5–89 mm.; 97.50, B6203, (2) 29.5–33 mm.; 100.40, H6204, (5) 28.5–42 mm.; 100.60, H6204, (2) 22.5–25 mm.; 100.65, C6303, (14) 27.5–84 mm.; 100.80, H6204, (3) 21–82.5 mm.; 108.63, C6303, (98) 25–86 mm.; 110.46, C6303, (1) 30 mm.; 110.50, B6203, (27) 23–41.5 mm.; 120.45, H6204, (4) 27–48.5 mm.; 120.50, H6204, (5) 32–42.5 mm.; 120.80, H6204, (1) 44 mm.; 120.90, H6204, (1) 21.5 mm.; 123.45, B6212, (22) 22–42 mm.; 123.50, B6203, (1) 26.5 mm.

19. *Bathylagus pacificus* Gilbert.

Figure 8B.

60.60, H6204, (4) 31–65.5 mm.; 60.80, H6204, (2) 30–51 mm.; 60.100, H6204, (3) 57–92 mm.; 80.90, H6204, (3) 42.5–149 mm.; 90.48a, H6105, (1) 127 mm.

20. *Bathylagus milleri* Jordan and Gilbert.

Figure 8B.

60.80, C6208, (5) 86–128 mm.; 60.120, H6204, (2) 37.5–45.5 mm.; 86.92, C6303, (10) 126–179 mm.; 87.80, C6303, (5) 128–163 mm.; 90.70, C6208, (6) 128–170 mm.



FIGURE 8.—Locations of capture of: A, *Leuroglossus stilbius*, *Bathylagus ochotensis*. B, *Bathylagus wesethi*, *Bathylagus pacificus*, *Bathylagus milleri*. C, *Macropinna microstoma*, *Dolichopteryx longipes*. D, *Argyropelecus pacificus*, *Argyropelecus intermedius*, *Sternoptyx diaphana*.



FIGURE 9.—*Bathylagus ochotensis*, juvenile, 25.5 mm. SL, station 73.50, H5204.



FIGURE 10.—*Bathylagus wesethi*, juvenile, 27 mm. SL, station 92.117, S4903.

This species has at times been referred to by its junior synonyms, *B. alascanus* Chapman and *B. arae* Schmidt (D. M. Cohen, personal communication).

OPISTHOPROCTIDAE

21. *Macropinna microstoma* Chapman.

Figure 8C.

60.70, H6204, (2) 18.5–20.5 mm.; 60.90, H6204, (1) 20.5 mm.; 83.77, C6303, (1) 31 mm.; 86.92, C6303, (11) 89–127 mm.; 87.80, C6303, (2) 120–133 mm.; 100.65, C6303, (1) 24.5 mm.

Previous collections in the eastern North Pacific had indicated this to be a rare and solitary species that did not attain a large size—no more than two specimens had been taken together in the same net, and the largest size reported was 40.7 mm. (Bradbury and Cohen, 1958:59). The large Cobb Mark-II pelagic trawl caught 11 specimens up to 133 mm. SL in one tow; such large nets clearly sample the bathypelagic zone more adequately. The 13 larger specimens (89–133 mm.) all appeared sexually mature; the females had large ovarian eggs.

The ovarian eggs showed the following (John S. MacGregor, personal communication). The largest developing eggs had diameters of 2.17 to 2.53

mm.—a 95-mm. SL female had 497 eggs. The largest remnant egg was 3.47 mm. in diameter and had a 0.91-mm. oil drop in a 123-mm. SL female that also contained 669 developing eggs of 0.76 to 1.01 mm. diameter.

22. *Dolichopteryx longipes* (Vaillant).

Figure 8C.

83.90, C6303, (1) 74 mm.; 97.65, C6303, (1) 138 mm.; 108.63, C6303, (4) 51–180 mm.; 110.140, H6204, (1) 53.5 mm.

These specimens were identified with a key prepared by D. M. Cohen.

STERNOPTYCHIDAE

23. *Argyropelecus pacificus* Schultz.

Figure 8D.

60.60, H6204, (2) 25–42 mm.; 60.70, H6204, (1) 30.5 mm.; 60.70, C6208, (1) 15.5 mm.; 60.90, C6208, (1) 56.5 mm.; 60.160, B6203, (2) 62.5–69.5 mm.; 80.55, H6204, (2) 17–18.5 mm.; 80.60, H6204, (6) 15–52.5 mm.; 80.60, C6208, (8) 42–58 mm.; 80.70, H6204, (1) 19 mm.; 80.70, C6208, (2) 47.5–54 mm.; 80.90, H6204, (2) 16.5–39 mm.; 83.74, C6303, (105) 17–80 mm.; 83.90, C6303, (62) 19.5–63 mm.; 84.67, C6303, (9) 18–27.5 mm.; 84.70, C6303, (1) 50 mm.; 86.92, C6303, (5) 19–68 mm.; 87.80, C6303, (3) 27–78.5 mm.; 90.45a, H6105, (1) 48 mm.; 90.45, H6204, (2) 18.5–19 mm.; 90.47, C6208, (37) 18–54 mm.; 90.48a, H6105, (1) 24.5 mm.; 90.60, C6208, (5) 50–59.5 mm.; 90.70, H6204,

(2) 21-45 mm.; 90.70, C6208, (11) 40-62 mm.; 90.120, H6204, (4) 12-37 mm.; 90.140, H6204, (1) 55 mm.; 94.32b, B6204, (2) 17-18 mm.; 97.40, C6303, (17) 36-73 mm.; 97.50, B6203, (2) 45-50 mm.; 97.65, C6303, (39) 22.5-68.5 mm.; 100.40, H6204, (2) 22-35.5 mm.; 100.60, H6204, (11) 24.5-66.5 mm.; 100.65, C6303, (45) 24-67 mm.; 100.90, H6204, (1) 55 mm.; 100.160, H6204, (1) 66.5 mm.; 108.63, C6303, (195) 13-69 mm.; 110.35, C6303, (1) 58 mm.; 110.46, C6303, (40) 21-67.5 mm.; 110.120, H6204, (3) 38-62 mm.; 111.36a, C6303, (ca. 30) adults and juveniles damaged and discarded at sea; 111.37b, C6303, (71) 21-70 mm.; 120.45, H6204, (1) 26 mm.; 120.50, H6204, (3) 15.5-45.5 mm.; 120.70, H6204, (9) 22-56.5 mm.; 120.80, H6204, (3) 51.5-59 mm.; 120.90, H6204, (5) 23.5-50.5 mm.; 123.50, B6203, (5) 15.5-49 mm.; 130.40, B6212, (12) 30.5-55.5 mm.; 140.35, B6212, (8) 21.5-52 mm.

24. *Argyrolepecus intermedius* Clarke.

Figure 8D.

60.70, H6204, (17) 9.5-23.5 mm.; 60.80, H6204, (2) 23-27 mm.; 60.90, H6204, (34) 12-34 mm.; 60.90, C6208, (2) 15.5-18 mm.; 60.100, H6204, (3) 14-25 mm.; 60.100, C6208, (2) 18.5-19 mm.; 60.120, B6203, (3) 23-24.5 mm.; 60.120, H6204, (8) 24-34 mm.; 60.140, H6204, (1) 26.5 mm.; 60.160, B6203, (1) 33 mm.; 60.160, H6204, (1) 33 mm.; 70.60, C6208, (1) 12.5 mm.; 80.55, H6204, (2) 16-19 mm.; 80.70, H6204, (1) 16.5 mm.; 80.80, H6204, (4) 22-25 mm.; 80.90, H6204, (4) 12-26 mm.; 80.140, C6208, (5) 18.5-33 mm.; 83.77, C6303, (8) 13.5-24 mm.; 83.90, C6303, (9) 18.5-31.5 mm.; 84.68, C6303, (1) 20 mm.; 84.92, B6303, (8) 20-28 mm.; 84.70, C6303, (1) 22 mm.; 86.92, C6303, (2) 20.5-23.5 mm.; 87.80, C6303, (1) 23 mm.; 87.90, C6303, (1) 24 mm.; 88.105a,

B6303, (8) 18-23 mm.; 90.60, C6208, (2) 16.5-19 mm.; 90.70, H6204, (1) 19 mm.; 90.70 C6208, (2) 17 mm.; 90.100, C6208, (15) 15-31.5 mm.; 90.120, H6204, (1) 14 mm.; 90.140, H6204, (1) 28.5 mm.; 90.150, C6208, (1) 21 mm.; 90.200, C6208, (1) 28 mm.; 100.60, H6204, (1) 15 mm.; 100.65, C6303, (3) 21.5-29 mm.; 100.80, H6204, (3) 19.5-28 mm.; 100.90, H6204, (4) 13.5-28.5 mm.; 100.120, H6204, (3) 24-26 mm.; 100.140, H6204, (2) 18.5-26.5 mm.; 110.120, H6204, (1) 20 mm.; 110.140, H6204, (1) 23.5 mm.; 110.160, H6204, (3) 11-26 mm.; 120.80, H6204, (9) 13.5-23.5 mm.; 120.90, H6204, (1) 15 mm.

25. *Argyrolepecus lychnus* Garman.

Figures 11 and 13A.

87.80, C6303, (1) 25 mm.; 90.45, H6204, (2) 15-17.5 mm.; 90.47, C6208, (1) 32 mm.; 90.48a, H6105, (2) 17.5-19.5 mm.; 90.120, H6204, (1) 12 mm.; 94.29a, C6208, (2) 30-30.5 mm.; 97.40, C6303, (4) 14-15.5 mm.; 97.50, B6203, (2) 21-39 mm.; 100.60, H6204, (2) 12-46 mm.; 100.90, H6204, (1) 48 mm.; 108.63, C6303, (2) 49-71.5 mm.; 110.35, C6303, (1) 17 mm.; 110.140, H6204, (1) 17.5 mm.; 120.45, H6204, (9) 14.5-27 mm.; 120.60, H6204, (2) 15.5 mm.; 120.80, H6204, (18) 20-61 mm.; 123.50, B6203, (6) 18-44 mm.; 130.40, B6212, (30) 17-58.5 mm.; 133.35, B6212, (1) 24.5 mm.; 137.50, B6203, (8) 19-43.5 mm.; 140.35, B6212, (3) 31-39 mm.

26. *Argyrolepecus hawaiiensis* Schultz.

Figures 12 and 13A.

60.60, H6204, (1) 12.5 mm.; 60.70, H6204, (3) 11-14.5 mm.; 60.80, H6204, (1) 16 mm.; 60.80, C6208, (2) 27-29 mm.; 60.90, H6204, (1) 13 mm.; 60.90, C6208, (2) 23-27 mm.; 60.100, H6204, (1) 30.5 mm.; 60.100, C6208, (4)

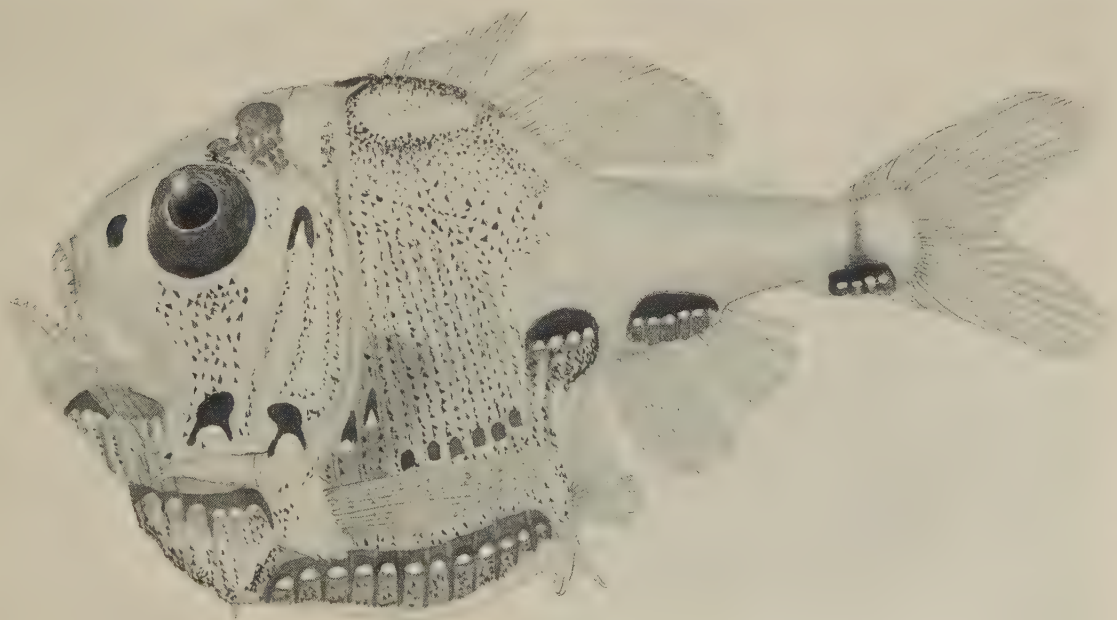


FIGURE 11.—*Argyrolepecus lychnus*, juvenile, 17 mm. SL, station 110.140, H6204.

20.5-56 mm.; 60.120, B6203, (4) 36-39 mm.; 60.120, H6204, (1) 43 mm.; 60.140, H6204, (1) 37 mm.; 60.160, B6303, (2) 39.5-44 mm.; 60.160, H6204, (3) 15-51 mm.; 60.200, H6204, (2) 48-53 mm.; 70.60, C6208, (2) 20 mm.; 70.80b, B6203, (2) 14-38 mm.; 70.100, C6208, (1) 38 mm.; 80.55, H6204, (1) 37 mm.; 80.60, C6208, (5) 14.5-21 mm.; 80.70, C6208, (3) 18.5-19.5 mm.; 80.80, H6204, (4) 24-43 mm.; 80.90, B6203, (2) 18.5-44.5 mm.; 80.100, B6203, (5) 36-50 mm.; 80.140, C6208, (2) 44-56 mm.; 80.150, C6208, (1) 50.5 mm.; 83.70c, B6303, (1) 39.5 mm.; 83.77, C6303, (18) 23-40.5 mm.; 83.90, C6303, (16) 18-47.5 mm.; 84.67, C6303, (9) 16-35.5 mm.; 84.68, C6303, (3) 20-35 mm.; 84.70, C6303, (6) 20-37.5 mm.; 84.92, B6303, (9) 19.5-45.5 mm.; 86.92, C6303, (5) 37-43 mm.; 87.80, C6303, (1) 28 mm.; 90.32, B6203, (3) 16-18 mm.; 90.45, H6204, (1) 15.5 mm.; 90.47, C6208, (1) 46.5 mm.; 90.60, C6208, (1) 49.5 mm.; 90.180, C6208, (1) 58 mm.; 93.31, C6303, (4) 25-39 mm.; 94.29a, C6208, (3) 28-29.5 mm.; 97.40, C6303, (17) 18-43.5 mm.; 97.50, B6203, (1) 26.5 mm.; 97.65, C6303, (4) 30.5-43 mm.; 100.40, H6204, (1) 21.5 mm.; 100.40, C6303, (1) 40 mm.; 100.60, H6204, (2) 14.5-39 mm.; 100.65, C6303, (5) 33-43.5 mm.; 100.80, H6204, (1) 20 mm.; 100.90, H6204, (1) 35.5 mm.; 100.120, H6204, (1) 62 mm.; 103.50, C6303, (1) 22 mm.; 108.63, C6303, (2) 25-28 mm.; 110.46, C6303, (1) 26.5 mm.; 110.50, B6203, (2) 23-47.5 mm.; 120.60, H6204, (2) 16-53 mm.; 123.50, B6203, (4) 19.5-60.5 mm.

Argyrolepecus hawaiiensis was first described as a subspecies of *Argyrolepecus lychnus* by Schultz (1961:615). With uncertainty, prompted by the small number of available specimens, Schultz recognized a complex of three subspecies:

A. l. lychnus Garman, eastern Pacific and Atlantic;

A. l. hawaiiensis Schultz, around and north of Hawaiian Islands;

A. l. sladeni Regan, western Pacific and Indian Oceans.

In none of our specimens of this type is the body depth of as great a percentage of standard length as that given for *A. sladeni* by Schultz (1961 and 1937:4), and we do not consider *A. sladeni*, if valid, to occur within our area of study.

We conclude that *A. hawaiiensis* is a species distinct from *A. lychnus*. In our study area *A. hawaiiensis* has the more temperate distribution, and *A. lychnus*, the more subtropical (fig. 13A); but both species, often represented by specimens of similar size, were taken together at 11 stations of the survey. With a comparable size series of juvenile and adult specimens of about 12 to 62 mm. SL, certain character differences readily distinguish the two species.

The upper preopercular spine in juvenile *A. hawaiiensis* curves outward and slightly dorsoposteriad in a nearly even arch, while in juvenile *A. lychnus* it curves outward and slightly ventroposteriad at its distal end. With increased body length this spine becomes relatively shorter and thicker in both species, but more strongly hooked upward in *A. hawaiiensis* and more strongly hooked downward and backward in *A. lychnus*.

Juvenile specimens of *A. hawaiiensis* possess considerably more lateral pigment along the posterior portion of the body (fig. 12). At about 14



FIGURE 12.—*Argyrolepecus hawaiiensis*, juvenile, 17 mm. SL, station 84.67, C6303.

mm. SL, *A. hawaiiensis* has a vertical band of pigment above the subcaudal photophores, a medial patch over the anal photophores, and a row of pigment spots along the lateral midline anterior to the anal photophores. Specimens of *A. lychnus* of the same size possess no pigment on the posterior portion of the body, and pigment in the areas above the subcaudal and anal photophores begins to show only faintly at about 17 mm.

At about 25 mm. SL, body pigment extends backward to the posterior edge of the anal group of photophores on both species. The vertical area between the anal and subcaudal photophores in *A. hawaiiensis* bears a row of pigment spots along the lateral midline (a posterior extension of the anterior row mentioned for the 14-mm. size). The area above the subcaudal photophores is strongly pigmented on both species and gives, on gross examination, the impression of a colorless, vertical band between the anal and subcaudal groups of photophores. This "banded" area fills in with pigment dorsoventrally in adults, and in 25-mm. specimens of *A. hawaiiensis* the beginning of this process is evident. Specimens of the same size of *A. lychnus* have little or no pigment in this area, and the lower portion of this area immediately between the anal and subcaudal photophores may be void of pigment in specimens of *A. lychnus* as large as 42 mm. SL.

Body depth in relation to standard length overlaps between the two species in the smaller juvenile sizes. At larger sizes *A. lychnus* has the deeper body; above 32 mm. SL the body depth of *A. lychnus* is about 62–71 percent SL and that of *A. hawaiiensis* about 54–60 percent SL.

An additional character useful in separating the two forms at sizes of about 45 mm. SL and larger is the formation of small spines along the ventral edges of the scales overlying the subcaudal photophores on specimens of *A. lychnus*. The spines start to develop on specimens between 40 and 45 mm. SL. These spines are absent on all specimens of *A. hawaiiensis* examined including the largest in our collections (62 mm. SL) and one of the paratypes at Scripps Institution of Oceanography (SIO H53-372, 52 mm.).

27. *Argyropelecus* sp.

110.50, B6203, (1) 15 mm.

This damaged specimen cannot be specifically identified.

28. *Sternoptyx diaphana* Hermann.

Figure 8D.

60.80, H6204, (1) 43 mm.; 60.100, H6204, (3) 13–18.5 mm.; 60.180, H6204, (5) 8–29 mm.; 70.200, H6204, (6) 11–37 mm.; 80.70, H6204, (2) 14.5–16 mm.; 80.100, H6204, (1) 34 mm.; 83.77, C6303, (1) 25 mm.; 84.67, C6303, (1) 22.5 mm.; 86.92, C6303, (13) 14.5–57 mm.; 87.80, C6303, (3) 19–59 mm.; 87.90, C6303, (1) 54 mm.; 90.45a, H6105, (2) 24–37 mm.; 90.48a, H6105, (1) 27 mm.; 90.160, H6204, (5) 24–42.5 mm.; 90.180, H6204, (1) 19.5 mm.; 90.200, H6204, (4) 7–27.5 mm.; 95.31a, B6204, (1) 15 mm.; 100.65, C6303, (1) 28 mm.; 100.80, H6204, (4) 15–37 mm.; 100.140, H6204, (3) 28.5–36.5 mm.; 100.160, H6204, (3) 13–28.5 mm.; 110.120, H6204, (3) 32–39.5 mm.; 110.160, H6204, (10) 12.5–51 mm.; 120.45, H6204, (1) 32.5 mm.; 120.50, H6204, (1) 26.5 mm.; 120.90, H6204, (1) 31 mm.

GONOSTOMATIDAE

29. *Gonostoma atlanticum* Norman?

Figure 13B.

80.55, H6204, (1) 65 mm.; 80.80, H6204, (1) 45 mm.; 80.90, H6204, (1) 56 mm.; 90.100, C6208, (1) 28.5 mm.; 97.65, C6303, (1) 52 mm.; 100.120, H6204, (1) 63.5 mm.

These specimens appear to represent *G. atlanticum* Norman, but are only tentatively identified because of the arrangement of the maxillary teeth. Grey (1960:107) described the last four enlarged maxillary teeth of *G. atlanticum* as having no interspace teeth. The above specimens possess interspace teeth between the enlarged teeth on the maxillary.

30. *Gonostoma ebelingi* Grey.

Figure 13B.

90.160, C6208, (1) 124 mm.

This specimen represents an appreciable range extension from the original area of its description, the Marshall Island area, by Grey (1960:109).

31. *Cyclothone* Goode and Bean.

This is probably the most abundant deepwater genus of fishes off the coast of California. However, the collection data indicate that hauls made shallower than 550 m. do not adequately sample their population. Of the several thousand specimens taken by the IKMWT (the most efficient device in present use for the consistent capture of these fishes), only about 11 percent were taken where the net was fishing above an estimated depth of 550 m., and nearly all of these fish were *C. signata* and *C. acclinidens*—apparently the two most abundant species in the California-Baja California area at any depth.



FIGURE 13.—Locations of capture of: A, *Argyropelecus hawaiiensis*, *Argyropelecus lychnus*. B, *Gonostoma atlanticum?*, *Gonostoma ebelingi*. C, *Cyclothone signata*, *Cyclothone sp.* D, *Cyclothone canina*, *Cyclothone acclinidens*, *Cyclothone atraria*.

Our first attempts to identify the abundant specimens of *Cyclothone* in the survey collections by literature existing at that time were unsatisfactory. A detailed examination was made of this group, and the results and conclusions are summarized below. At least five species of *Cyclothone* are represented in our collections.

Some of the specimens of *C. signata* from the more offshore localities may represent the tersely described and inadequately known *C. alba* Brauer (B. N. Kobayashi, personal communication).

The form we designate as *Cyclothone* sp. (number 33) may be an undescribed species. There is a possibility that it represents *C. pseudopallida*, recently described by Mukhacheva (1964) (B. N. Kobayashi, personal communication).

Although *Cyclothone microdon* (Günther) has been reported from California waters, none of the specimens taken in the survey can be definitely attributed to this species. *C. pallida* Brauer has

also been reported off California, but we find that the form here closely resembles Gilbert's description of *C. canina* (1905:604); especially significant is Gilbert's description of the palatine and pterygoid teeth of *C. canina*—"palatine teeth confined to the anterior end, in two small detached groups—pterygoid teeth all small, forming a single, somewhat irregular series." Actually his two small detached groups of palatines were one group (anterior) of palatines and one group (posterior) of pterygoids, as is typical of the genus. The irregular series of pterygoid teeth is thus far unique in this genus. They lie along the upper edge of the bone for nearly its entire length (fig. 14 C); however, the size and number of these teeth may be intraspecifically variable. As mentioned, this fact alone separates *C. canina* from other California species, and, unless the type specimens of *C. pallida* are found to contain such an arrangement of teeth (all other characters being equal), the two forms must certainly stand as distinct.

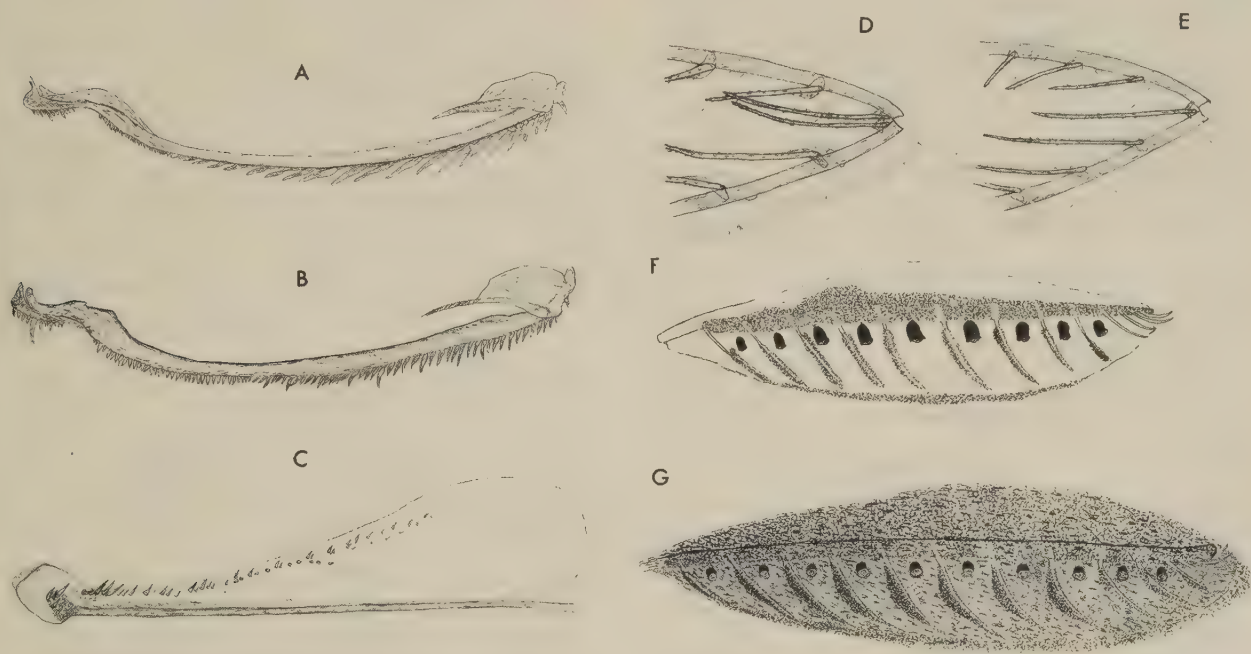


FIGURE 14.—*Cyclothone*. A, upper jaw of *C. acclinidens* showing the arrangement of teeth along the maxillary and premaxillary; the premaxillary is at the extreme left; the long slender bone possessing most of the teeth is the maxillary; and the small bone at upper right is the supramaxillary. B, upper jaw of *C. canina*. C, palatine and pterygoid bones of *C. canina* showing the unique row of teeth on the entopterygoid; the anterior end is at the left. D, posterior part of the first gill arch of *Cyclothone* sp. showing the typical arrangement of two gillrakers at the angle. E, posterior part of the first gill arch of *C. signata* showing the unique arrangement of only one gillraker at the angle of the epibranchial and ceratobranchial bones. F, branchiostegal membrane and rays of *C. signata* showing photophore and pigment arrangement. G, branchiostegal membrane and rays of *C. acclinidens* showing photophore and pigment arrangement.

All California species possesses a photophore immediately below the eye and slightly forward of the eye's midline, a photophore above the posterior extremity of the maxillary on a level with the eye, and a photophore immediately behind the angle of the preopercle. Other photophores are mentioned in table 2. The photophores between the bases of the pelvic and anal fins have not been dealt with as a separate unit because an exact dividing line between these and the anal-to-caudal group is difficult to determine in many fish. Generally, *C. signata* has four photophores between the pelvics and anal and the other species have five. The first two pairs in this group are markedly close-set in *Cyclothone* sp., while the interspaces are equal or slightly greater posteriorly in the other species.

KEY TO ADULTS OF THE CALIFORNIA AND BAJA CALIFORNIA SPECIES OF THE GENUS *CYCLOTHONE*

I. Branchiostegal membranes without pigment except for a thin line over all but a few of the most posterior rays and along the upper and lower margins (fig. 14F). Roof of mouth pigmented mainly along its midline. Gill cavities nearly colorless. Gillrakers totaling less than 20 on the lateral side of the first gill arch. One or two gillrakers at angle of first gill arch.

A. Total gillrakers on lateral side of first gill arch not more than 15 (usually 4+10). Only one gillraker at angle of first gill arch (fig. 14E). -----

-----*C. signata* Garman.

B. Total gillrakers on lateral side of first arch 17-19

(the position of the medial rakers on the arch accentuated by a thin pigment line). Two gillrakers at angle of first gill arch (fig. 14D).---*Cyclothone* sp.
II. Entire branchiostegal membranes and most of the oral and gill cavities darkly pigmented (fig. 14G). Gillrakers more than 20 on the lateral side of the first gill arch. Two gillrakers at angle of first gill arch.

A. None of the teeth on the premaxillary directed strongly anteroventrad; generally, every third or fourth of the oblique teeth enlarged; canines conspicuous on premaxillary (fig. 14B). Entopterygoid teeth not confined to an anterior cluster (fig. 14C). -----*C. canina* Gilbert.

B. Teeth along posterior three quarters of maxillary directed strongly anteroventrad, generally increasing in obliqueness and decreasing in size anteriorly; no conspicuous canines on the premaxillary (fig. 14A). Entopterygoid teeth confined to an anterior cluster.

1. Branchiostegal photophores 8 or 9. Branchiostegal rays 12. Pigmentation dark brown and usually persistent; photophores relatively small; scale pockets conspicuous. ----*C. atraria* Gilbert.

2. Branchiostegal photophores 10 or 11. Branchiostegal rays 14. Pigmentation light brown or greyish; photophores of relatively moderate size; scale pockets not conspicuous. -----
-----*C. acclinidens* Garman.

32. *Cyclothone canina* Gilbert.

Figures 13D, 14B, and 14C.

60.60, H6204, (3) 24-61 mm.; 60.80, H6204, (1) 62 mm.; 60.100, H6204, (4) 24-48.5 mm.; 60.140, H6204, (3) 24-49 mm.; 60.180, H6204, (6) 22-70 mm.; 70.200, H6204, (2) 24.5-63.5 mm.; 80.70, H6204, (1) 56 mm.; 86.92, C6303,

TABLE 2.—Comparative morphological data for the five species of *Cyclothone* occurring off the coasts of California and Baja California

Morphological character	Species				
	<i>signata</i>	Sp. No. 33	<i>canina</i>	<i>acclinidens</i>	<i>atraria</i>
Dorsal rays.....	13-14	13-15	14-15	13-15	13-14.
Anal rays.....	19-20	19-21	18-19	18-20	18-19.
Pectoral rays.....	8-10	9	11	9-10	9-10.
Pelvic rays.....	6	6	6	6	6.
Branchiostegal rays.....	13	14	14	14	12.
Gillrakers.....	3-4+9-10	6-7+11-12	9-10+14-16	7-8+14-15	8-9+14.
Vertebrae.....	13+18-19	12-13+19-20	13+18-19	13+18	13+19.
Photophores:					
Branchiostegal.....	8-9	9-11	9-10	10-11	8-9.
Lateral.....	7	7+1 or 7+2	7+1 or 7+2	7+2	7+2.
Isthmus to pelvic.....	13	13	13	13	13.
Pelvic to caudal.....	18	20-21	20-21	18-19	19-21.
Relative size.....	Small	Moderate	Large	Large	Moderately large.
Body shape.....	Moderately slender	Very slender	Slender	Moderately slender	More robust than others.
General body color.....	Pale—rarely pigment flecks on flanks.	Pale or flanks brown	Flanks brown	Brown flanks or grey cast.	Dark brown.
Pigment visible between inter-neurals and interhaemals.	Yes	Yes	Yes	Yes	No.
Premaxillary teeth.....	Slight irregular	Irregular	2-4 distinct canines	Irregular, nearly forming canines.	Irregular, nearly forming canines.
Slope of maxillary teeth.....	Moderate	Moderate	Moderate	Very strong	Strong.
Vomerine teeth.....	Usually absent, minute if present.	Present	Present	Present	Present.
Position of anus between pelvics and anal.	Immediately behind pelvic base.	Much nearer pelvics than anal.	Midway	Midway or less	Midway.
Scale pockets conspicuous.....	No	No	No	No	Yes.
Number of rakers at angle of first gill arch.	1	2	2	2	2.

(4) 31.5–57 mm.; 87.80, C6303, (1) 58.5 mm.; 87.90, C6303, (1) 43.5 mm.; 90.120, H6204, (3) 43–58 mm.; 90.160, H6204, (4) 31–59 mm.; 90.200, H6204, (9) 30.5–58.5 mm.; 100.60, H6204, (6) 52–62 mm.; 100.80, H6204, (2) 41–51.5 mm.; 100.100, H6204, (5) 40–62 mm.; 100.140, H6204, (4) 31–59 mm.; 100.160, H6204, (6) 47–60 mm.; 110.140, H6204, (2) 25–33 mm.; 110.160, H6204, (8) 28–60 mm.; 120.50, H6204, (2) 56–58 mm.; 120.70, H6204, (1) 44 mm.; 120.90, H6204, (4) 42–62 mm.

33. *Cyclothone* sp.

Figures 13C and 14D.

60.60, H6204, (8) 27–42.5 mm.; 60.80, H6204, (16) 18–47 mm.; 60.90, H6204, (6) 19–31.5 mm.; 60.100, H6204, (34) 24–47 mm.; 60.140, H6204, (11) 26–47.5 mm.; 60.180, H6204, (27) 15–46 mm.; 70.200, H6204, (20) 21.5–42 mm.; 80.90, H6204, (2) 35–37.5 mm.; 83.77, C6303, (6) 32–45 mm.; 86.92, C6303, (7) 27–37.5 mm.; 90.48a, H6105, (3) 36.5–41 mm.; 90.120, H6204, (7) 30.5–36 mm.; 90.160, H6204, (4) 12–36 mm.; 90.180, H6204, (1) 28.5 mm.; 90.200, H6204, (11) 20–38 mm.; 97.65, C6303, (2) 27 mm.; 100.65, C6303, (1) 26.5 mm.; 100.80, H6204, (6) 35.5–41.5 mm.; 100.100, H6204, (4) 36–38.5 mm.; 100.140, H6204, (9) 18–40 mm.; 100.160, H6204, (9) 29–38.5 mm.; 108.63, C6303, (1) 27 mm.; 110.160, H6204, (2) 35–40 mm.

34. *Cyclothone signata* Garman.

Figures 13C, 14E, and 14F.

60.60, H6204, (95) 19–36 mm.; 60.60, C6208, (1) 26 mm.; 60.70, H6204, (7) 19–30 mm.; 60.80, H6204, (108) 15–36 mm.; 60.90, H6204, (9) 24–29 mm.; 60.100, H6204, (99) 14–38.5 mm.; 60.140, H6204, (128) 13.5–36 mm.; 60.180, H6204, (97) 16–34 mm.; 70.200, H6204, (83) 18.5–34.5 mm.; 79.54, B6303, (9) 16.5–29.5 mm.; 80.55, H6204, (23) 19–29 mm.; 80.60, H6204, (49) 16–31 mm.; 80.70, H6204, (98) 12.5–34.5 mm.; 80.70, C6208, (1) 22.5 mm.; 80.75, B6303, (1) 20 mm.; 80.80, H6204, (37) 14–32 mm.; 80.90, H6204, (152) 17–34 mm.; 80.100, H6204, (93) 20–30 mm.; 80.170, C6208, (1) 24 mm.; 80.200, H6204, (1) 28.5 mm.; 83.77, C6303, (114) 21.5–33 mm.; 83.90, C6303, (67) 17.5–30 mm.; 84.70, C6303, (1) 28 mm.; 86.92, C6303, (73) 21–34 mm.; 87.80, C6303, (3) 24.5–33.5 mm.; 87.90, C6303, (2) 28–38 mm.; 90.45a, H6105, (16) 23.5–33.5 mm.; 90.48a, H6105, (132) 16–33 mm.; 90.48b, H6105, (9) 20–30 mm.; 90.60, H6204, (2) 24–38 mm.; 90.60, C6208, (21) 16–26 mm.; 90.70, H6204, (1) 21 mm.; 90.70, C6208, (15) 21.5–32.5 mm.; 90.100, C6208, (17) 17–26 mm.; 90.120, H6204, (92) 12.5–36 mm.; 90.140, H6204, (1) 19.5 mm.; 90.140, C6208, (1) 25 mm.; 90.160, H6204, (51) 16–32.5 mm.; 90.160, C6208, (1) 30 mm.; 90.200, H6204, (41) 15–33 mm.; 97.40, C6303, (21) 22–30 mm.; 97.65, C6303, (94) 17.5–38 mm.; 100.60, H6204, (6) 25–33 mm.; 100.65, C6303, (409) 17–35 mm.; 100.80, H6204, (91) 17–36 mm.; 100.100, H6204, (29) 10–34.5 mm.; 100.140, H6204, (22) 18.5–35 mm.; 100.160, H6204, (31) 17.5–35.5 mm.; 108.63, C6303, (149) 19.5–36 mm.; 110.35, C6303, (3) 26–30 mm.; 110.46, C6303, (29) 23–33 mm.; 110.120, H6204, (25) 22–35 mm.; 110.140, H6204, (13) 18–28.5 mm.; 110.160, H6204, (33) 16–32 mm.; 111.37b, C6303, (9) 25–30 mm.; 118.43, B6212, (24) 21.5–33.5 mm.; 120.45, H6204, (12) 20–29 mm.; 120.50, H6204,

(2) 27–32 mm.; 120.60, H6204, (4) 25–30 mm.; 120.70, H6204, (8) 22.5–33 mm.; 120.90, H6204, (16) 22.5–32 mm.; 123.50, B6203, (1) 22 mm.; 130.40, B6212, (5) 22.5–26.5 mm.; 140.35, B6212, (14) 23.5–32 mm.

35. *Cyclothone acclinidens* Garman.

Figures 13D, 14A, and 14G.

60.60, H6204, (33) 15–54.5 mm.; 60.70, H6204, (3) 27–42.5 mm.; 60.80, H6204, (13) 26–55.5 mm.; 60.90, H6204, (1) 34 mm.; 60.100, H6204, (10) 28–55 mm.; 60.140, H6204, (37) 27–56.5 mm.; 60.180, H6204, (7) 31.5–58 mm.; 70.200, H6204, (5) 30.5–40 mm.; 80.55, H6204, (41) 20–40 mm.; 80.60, H6204, (4) 21–46 mm.; 80.70, H6204, (23) 22.5–58 mm.; 80.80, H6204, (1) 31 mm.; 80.90, H6204, (66) 20.5–57 mm.; 80.100, H6204, (32) 21–45.5 mm.; 83.77, C6303, (86) 21–37 mm.; 84.70, C6303, (4) 35–53 mm.; 86.92, C6303, (141) 26.5–56 mm.; 87.80, C6303, (57) 30–55 mm.; 87.90, C6303, (6) 32.5–50 mm.; 90.45a, H6105, (71) 23.5–43.5 mm.; 90.48a, H6105, (207) 15.5–43.5 mm.; 90.48b, H6105, (10) 16.5–24.5 mm.; 90.120, H6204 (29) 19–56 mm.; 90.160, H6204, (6) 32.5–50.5 mm.; 90.200, H6204, (16) 23–58 mm.; 95.31a, B6204, (2) 26–31 mm.; 97.65, C6303, (7) 17.5–32 mm.; 100.60, H6204, (98) 20.5–53 mm.; 100.65, C6303, (12) 25–45.5 mm.; 100.80, H6204, (62) 23–58 mm.; 100.100, H6204, (65) 14–56 mm.; 100.140, H6204, (18) 25.5–54 mm.; 100.160, H6204, (16) 24–57 mm.; 108.63, C6303, (12) 18–34 mm.; 110.35, C6303, (1) 26 mm.; 110.46, C6303, (3) 22–27 mm.; 110.120, H6204, (88) 19–56 mm.; 110.140, H6204, (11) 19–35 mm.; 110.160, H6204, (35) 16–56 mm.; 111.37b, C6303, (5) 17–30 mm.; 118.43, B6212, (16) 17.5–31 mm.; 120.45, H6204, (4) 21.5–25.5 mm.; 120.50, H6204, (174) 17–51 mm.; 120.60, H6204, (1) 25 mm.; 120.70, H6204 (152) 14.5–55 mm.; 120.90, H6204, (276) 19.5–63 mm.; 130.40, B6212, (81) 13.5–38.5 mm.; 133.35, B6212, (3) 17–22 mm.; 140.35, B6212, (77) 14–40 mm.

36. *Cyclothone atraria* Gilbert.

Figure 13D.

60.60, H6204, (4) 36.5–50 mm.; 60.70, H6204, (1) 51 mm.; 60.80, H6204, (5) 21–49.5 mm.; 60.100, H6204, (6) 31–56 mm.; 60.140, H6204, (6) 37.5–51.5 mm.; 60.180, H6204, (11) 28–51 mm.; 70.200, H6204, (9) 28–54.5 mm.; 80.90, H6204, (1) 55 mm.; 120.70, H6204, (1) 53.5 mm.

37. *Diplophos* sp.

133.35, B6212, (1) 50 mm.

It is not possible to identify this slightly damaged specimen specifically from the revision by Grey (1960:57–125).

38. *Valenciennellus tripunctulatus* (Esmark)?

Figure 15A.

70.200, H6204, (1) 28 mm.; 73.200, B6203, (2) 25 mm.; 90.120, H6204, (1) dis. adult; 90.160, H6204, (1) ca. 10 mm.; 90.180, H6204, (1) 25 mm.; 90.200, H6204, (1) 25.5 mm.

This specific identification is questioned because most of these specimens have four groups of anal

to caudal (AC) photophores rather than the five groups reportedly characteristic for *V. tripunctulatus*; this difference may indicate that these specimens are actually *V. stellatus* Garman. This problem was discussed by Grey (1960: 68).

39. *Danaphos oculatus* (Garman).

Figure 15A.

60.60, H6204, (1) 19.5 mm.; 60.70, H6204, (7) 20–25 mm.; 60.80, H6204, (4) 22–38 mm.; 60.90, H6204, (7) 20.5–31 mm.; 60.90, C6208, (2) 32 mm.; 60.100, H6204, (2) 22.5–23.5 mm.; 60.120, H6204, (21) 29–40 mm.; 60.160, B6203, (3) 34.5–36 mm.; 60.160, H6204, (1) 31 mm.; 60.180, H6204, (1) 40 mm.; 70.60, C6208, (1) 23 mm.; 70.200, H6204, (1) 44 mm.; 80.55, H6204, (3) 30–30.5 mm.; 80.60, H6204, (1) 27 mm.; 80.70, H6204, (3) 26.5–38.5 mm.; 80.75, B6303, (1) 22.5 mm.; 80.80, H6204, (14) 26–39 mm.; 80.90, H6204, (7) 24–38 mm.; 80.100, H6204, (3) 30–32 mm.; 80.140, C6208, (1) 30 mm.; 83.77, C6303, (44) 27–40 mm.; 83.90, C6303, (61) 23–40.5 mm.; 84.67, C6303, (3) 29–30 mm.; 86.92, C6303, (4) 28–30 mm.; 87.80, C6303, (4) 34.5–40 mm.; 90.32, B6203, (2) 33 mm.; 90.45a, H6105, (1) 32.5 mm.; 90.60, H6204, (1) adult, damaged; 90.70, H6204, (4) 31–37 mm.; 90.110, B6203, (1) 36 mm.; 90.120, H6204, (1) 31 mm.; 90.140, C6208, (2) 24–30.5 mm.; 90.160, H6204, (1) 37.5 mm.; 97.65, C6303, (3) 20.5–39 mm.; 100.60, H6204, (1) 34 mm.; 100.65, C6303, (18) 25.5–39 mm.; 100.80, H6204, (9) 31–35 mm.; 100.90, H6204, (1) 34 mm.; 100.160, H6204, (1) 32.5 mm.; 108.63, C6303, (5) 29–38 mm.; 110.120, H6204, (2) 25–35 mm.; 110.140, H6204, (1) 29 mm.; 110.160, H6204, (2) 32.5–35 mm.; 120.45, H6204, (1) 29 mm.; 120.60, H6204, (1) 32 mm.; 120.70, H6204, (1) 34 mm.; 140.35, B6212, (1) 34 mm.

40. *Vinciguerrria nimbaria* (Jordan and Williams).

Figure 15B.

60.200a, B6203, (2) 24.5–38 mm.; 73.200, B6203, (1) 39 mm.; 80.140, C6208, (1) 23.5 mm.; 80.170, C6208, (2) 16–22 mm.; 90.110, C6303, (4) 20–43 mm.; 90.150, C6208, (10) all ca. 26 mm.; 90.160, H6204, (2) 18–19.5 mm.; 90.180, H6204, (1) 39.5 mm.; 93.100, C6303, (1) 21.5 mm.; 100.140, H6204, (1) 20 mm.; 100.160, H6204, (1) 26 mm.

41. *Vinciguerrria lucetia* (Garman).

Figure 15B.

83.77, C6303, (1) 34 mm.; 83.90, C6303, (1) 35.5 mm.; 87.80, C6303, (1) 42 mm.; 90.48b, H6105, (1) ca. 10 mm.; 90.120, C6208, (5) 16.5–28 mm.; 90.140, H6204, (1) 49.5 mm.; 90.150, C6208, (7) 17–19 mm.; 100.100, H6204, (3) 32.5–42 mm.; 100.160, H6204, (1) 24 mm.; 110.100, H6204, (1) 24 mm.; 110.120, H6204, (3) 28–44 mm.; 110.140, H6204, (1) 19 mm.; 120.45, B6212, (24) 17–22.5 mm.; 120.60, H6204, (4) 34–36 mm.; 120.70, H6204, (4) 28–41 mm.; 120.80, H6204, (10) 31.5–47 mm.; 120.90, H6204, (19) 27.5–49 mm.; 123.45, B6212, (158) 18–44.5 mm.; 123.50, B6203, (3) 22–27 mm.; 127.45, B6212, (7) 21–32.5 mm.; 130.40, B6212, (142) 15–56.5 mm.; 133.35, B6212, (87)

15.5–53.5 mm.; 137.35, B6212, (536) 12.5–48.5 mm.; 137.50, B6203, (7) 28.5–52 mm.; 140.35, B6212, (388) 14.5–50 mm.

42. *Vinciguerrria poweriae* (Cocco).

Figure 15B.

60.120, B6203, (2) 24–28 mm.; 60.160, B6203, (1) 26 mm.; 60.180, B6203, (1) 24.5 mm.; 60.200, H6204, (1) 31 mm.; 70.200, H6204, (1) 18 mm.; 73.200, B6203, (2) 27–30 mm.; 80.140, C6208, (2) 23–23.5 mm.; 80.200, C6208, (1) 34 mm.; 83.77, C6303, (2) 23–28 mm.; 90.110, C6303, (8) 26–33.5 mm.; 90.120, C6208, (2) 17.5 mm.; 90.124, C6208, (2) 16 mm.; 90.160, H6204, (2) 17.5–18 mm.; 90.160, C6208, (1) 27.5 mm.; 90.200, H6204, (1) 17.5 mm.; 92.115, B6303, (1) 18.5 mm.

The specimens from station 83.77 are closer to the continent (about 195 km. (120 miles) offshore) than is usual for this species (see Ahlstrom and Counts 1958, fig. 25).

43. *Vinciguerrria* sp.

90.140, C6208, (3) 18–20 mm.

These damaged specimens are unidentifiable to species.

44. *Ichthyococcus elongatus* Imai.

Figure 15C.

80.70, H6204, (1) 65 mm.

This record extends the known range of the species from Japan and lat. 41°42' N., long. 150° 00' W. to near the coast of California and also extends its geographical range into that of *I. irregularis* as described by Rechnitzer and Böhlke (1958).

45. *Ichthyococcus irregularis* Rechnitzer and Böhlke.

Figure 15C.

90.47, C6208, (1) 37 mm.; 100.60, H6204, (1) 61.5 mm.; 108.63, C6303, (1) 51 mm.; 120.90, H6204, (1) 41 mm.

STOMIATIDAE

46. *Stomias atriventer* Garman.

Figure 15D.

82.69, C6303, (1) 59 mm.; 84.70, C6303, (1) 209 mm.; 86.92, C6303, (5) 52.5–227 mm.; 87.80, C6303, (2) 195–218 mm.; 87.90, C6303, (1) 74 mm.; 90.45a, H6105, (1) 202 mm.; 90.48a, H6105, (1) 116 mm.; 90.110, C6303, (1) 228 mm.; 95.31a, B6204, (1) 158 mm.; 97.40, C6303, (1) 232 mm.; 97.65, C6303, (1) 45 mm.; 100.40, H6204, (3) 122–204 mm.; 100.40, C6303, (1) 161 mm.; 100.100, H6204, (1) 29 mm.; 108.63, C6303, (24) 128–235 mm.; 110.35, C6303, (3) 123–205 mm.; 110.40, H6204, (1) 142 mm.; 110.46, C6303, (7) 180–226 mm.; 120.45, H6204, (8) 138–214 mm.; 120.45, B6212, (1) 48 mm.; 120.50, H6204, (1) 212 mm.; 120.60, H6204, (1) 131 mm.; 120.80, H6204, (1) 186 mm.;



FIGURE 15.—Locations of capture of: A, *Valenciennellus tripunctulatus*?, *Danaphos oculatus*. B, *Vinciguerria nimbaria*, *Vinciguerria lucetia*, *Vinciguerria poweriae*. C, *Ichthyococcus elongatus*, *Ichthyococcus irregularis*. D, *Stomias atriventer*, *Stomias* sp., *Chauliodus macouni*.

123.50, B6203, (7) 83.5-214 mm.; 137.35, B6212, (1) 49 mm.; 137.50, B6203, (2) 127-178 mm.

This species was listed as a subspecies of *Stomias boa* (Risso) by Ege (1934:23) but is now generally regarded as a distinct species. In a few of the 78 specimens collected during the survey, the barbel was broken off, but the normal three equal-sized filaments at the end of the barbel were present in the others, except one. On the exceptional specimen, one of the three filaments was branched to near its base, giving the superficial appearance of four filaments at the end of the barbel.

47. *Stomias* sp.

Figure 15D.

110.35, H6204, (1) 189 mm.

This specimen, occurring within the range of *S. atriventer*, represents either a morphological variant or an undescribed species. It differs in a number of characters from *S. atriventer* and from all known species of *Stomias* in having six equal-sized filaments, each with a separate base, at the end of the barbel.

MELANOSTOMIATIDAE

48. *Leptostomias* sp.

90.200, C6208, (1) 186 mm.

This specimen was taken about 1,000 km. (620 miles) WSW. of Point Conception, Calif. The number and taxonomic limits of the species of this genus are uncertain, and this specimen is not specifically identified, pending needed study of the genus.

49. *Opostomias mitsuui* Imai.

60.80, C6208, (1) 164 mm.; 83.77, C6303, (1) 77 mm.

These specimens, taken about 185 km. (115 miles) west of San Francisco and about 195 km. (120 miles) SE. of Point Conception, Calif., are the first of this species to be reported from waters off California. The three known species of this genus, including *O. micripnus* (Günther) and *O. gibsonpacei* Barnard, appear to be valid, but further comparison is necessary (R. H. Gibbs, personal communication).

50. *Flagellostomias boureei* Zugmayer.

80.80, H6204, (1) 134 mm.; 87.80, C6303, (1) 186 mm.

These specimens, taken about 200 and 240 km. (125 and 150 miles) off Point Conception, Calif.,

differ only slightly from the detailed description of *F. boureei* from the western Atlantic by Beebe and Crane (1939:179-185). Comparison of other Atlantic and Pacific specimens indicates that they are the same species (R. H. Gibbs, personal communication).

51. *Melanostomias valdiviae* Brauer.

86.92, C6303, (2) 163-175 mm.

These two specimens taken about 305 km. (190 miles) SSW. of Point Conception, and one specimen in the collections of Scripps Institution of Oceanography collected off San Juan Seamount, constitute the first records of this species in this area.

52. *Photoneustes margarita* (Goode and Bean).

Figure 16A.

60.120, B6203, (1) 138 mm.; 60.160, H6204, (1) 171 mm.; 60.200, H6204, (2) 118-193 mm.; 80.90, H6204, (1) 135 mm.; 90.160, C6208, (1) 45 mm.; 93.100, C6303, (1) 138 mm.; 100.80, H6204, (1) 50.5 mm.; 100.120, H6204, (1) 91 mm.; 100.140, H6204, (1) 68 mm.

These specimens appear to be this species, re-described from material from the North Atlantic by Beebe and Crane (1939:175-179). The above listed specimens vary considerably in several characters, especially barbel structure (at least some of this variation is ontogenetic). Although more than one species may be represented, the variation in barbel structure is thought to be intraspecific.

53. *Tactostoma macropus* Bolin.

Figure 16A.

60.60, H6204, (1) 175 mm.; 60.80, H6204, (1) 85 mm.; 60.80, C6208, (13) 54.5-325 mm.; 60.90, H6204, (3) 143-234 mm.; 60.90, C6208, (9) 135-247 mm.; 60.100, C6208, (1) 231 mm.; 60.120, B6203, (1) 232 mm.; 60.120, H6204, (1) 228 mm.; 66.100, C6208, (1) 200 mm.; 80.55, H6204, (2) 85.5-233 mm.; 80.60, H6204, (2) 91-231 mm.; 80.60, C6208, (2) 156-204 mm.; 80.90-5N, B6203, (2) 91-91.5 mm.; 80.130, C6208, (1) 44 mm.; 82.69, C6303, (1) 81 mm.; 83.77, C6303, (4) 63-163 mm.; 84.92, B6303, (2) 56-66 mm.; 86.92, C6303, (3) 210-293 mm.; 87.80, C6303, (1) 320 mm.; 88.105a, B6303, (1) 76 mm.; 90.60, C6208, (1) 101 mm.

54. *Bathophilus flemingi* Aron and McCrery.

Figure 16A.

60.80, C6208, (1) 64 mm.; 60.120, B6203, (1) 65 mm.; 66.100, C6208, (1) 41.5 mm.; 80.60, C6303, (3) 76-85 mm.; 80.90, H6204, (1) 72.5 mm.; 82.69, C6303, (1) 65 mm.; 84.67, C6303, (1) 84 mm.; 86.92, C6303, (1) 131 mm.; 87.200, B6203, (1) 36 mm.; 88.105b, B6303, (2) 68-82 mm.;



FIGURE 16.—Locations of capture of: A, *Photonectes margarita*, *Tactostoma macropus*, *Bathophilus flemingi*. B, *Idiacanthus antrostomus*, *Borostomias panamensis*, *Aristostomias scintillans*. C, *Hierops crockeri*, *Electrona rissoi*. D, *Hygophum* sp., *Tarletonbeania crenularis*.

90.140, H6204, (1) 56.5 mm.; 90.160, H6204, (1) 33 mm.; 97.40, C6303, (1) 97 mm.; 97.65, C6303, (4) 75–120 mm.; 100.65, C6303, (1) 70 mm.; 100.120, H6204, (1) 62 mm.; 100.140, H6204, (1) 67 mm.

B. flemingi was described as a new species from the Eastern North Pacific (Aron and McCrery, 1958:181), although it differed only slightly from the inadequately described *B. indicas* Brauer from the Indian Ocean. Recent evidence indicates that the two species may be synonymous (R. H. Gibbs, personal communication). We found a range in pelvic fin rays of 2 + 2 to 2 + 5 in several specimens counted.

55. Melanostomiidae, unidentified.

60.180, H6204, (4) 18–30 mm.

These larval specimens have not been identified.

IDIACANTHIDAE

56. *Idiacanthus antrostomus* Gilbert.

Figure 16B.

60.80, H6204, (5) 53–118 mm.; 60.80, C6208, (1) 216 mm.; 60.90, H6204, (1) 207 mm.; 60.90, C6208, (1) 154 mm.; 60.100, H6204, (4) 65–79 mm.; 60.100, C6208, (1) 149 mm.; 60.120, B6203, (3) 168–269 mm.; 60.160, B6203, (1) 160 mm.; 60.180, H6204, (3) 62–124 mm.; 70.80b, B6203, (2) 100–137 mm.; 70.80–5N, B6203, (1) 121 mm.; 73.200, B6203, (1) dis.; 80.55, H6204, (1) 135 mm.; 80.70, H6204, (1) 67 mm. (larva); 80.100, B6203, (1) 241 mm.; 82.69, C6303, (2) 99–252 mm.; 83.77, C6303, (16) 64–348 mm.; 84.70, C6303, (1) 150 mm.; 84.92, B6303, (1) 115 mm.; 86.92, C6303, (17) 61–371 mm.; 87.80, C6303, (4) 66–266 mm.; 87.90, C6303, (4) 123–260 mm.; 88.105a, B6303, (1) 344 mm.; 90.48a, H6105, (2) 69–333 mm.; 90.60, H6204, (1) 73 mm.; 90.110, C6303, (4) 236–300 mm.; 90.120, H6204, (2) dis., 70 mm.; 90.140, H6204, (1) 95 mm.; 90.140, C6208, (2) 58–84 mm.; 90.150, C6208, (1) 125 mm.; 90.160, H6204, (1) 65 mm.; 90.160, C6208, (1) 73 mm.; 90.180, H6204, (1) 104 mm.; 90.200, H6204, (1) 42 mm.; 93.100, C6303, (4) 60–342 mm.; 97.40, C6303, (10) 66–320 mm.; 97.65, C6303, (1) 210 mm.; 100.60, H6204, (1) 249 mm.; 100.65, C6303, (8) 60.5–274 mm.; 100.80, H6204, (2) dis., 59 mm.; 100.90, H6204, (1) 233 mm.; 103.50, C6303, (1) 259 mm.; 108.63, C6303, (9) 134–343 mm.; 110.46, C6303, (3) 209–348 mm.; 110.35, C6303, (8) 156–212 mm.; 110.120, H6204, (1) 98 mm.; 110.160, H6204, (2) 77–115 mm.; 120.80, H6204, (1) 292 mm.; 123.45, B6212, (1) 144 mm.; 123.50, B6203, (7) 178–292 mm.

This is probably the only species of this genus that occurs in the eastern Pacific; as *I. panamensis* Regan and Trewavas, described from the Gulf of Panama, may be a junior synonym of *I. antrostomus* (R. H. Gibbs, personal communication). An adult male of 70 mm. SL from station 60.80, H6204 is larger than maximum sizes of males re-

ported as 44 mm. (adult) and 48 mm. (postlarva) by Beebe (1934:234–236). This was the most abundant and ubiquitous of the 12 species of the suborder Stomiatoidei taken on the survey.

ASTRONESTHIDAE

57. *Borostomias panamensis* Regan and Trewavas.

Figure 16B.

80.90, H6204, (1) 244 mm.; 84.70, C6303, (1) 195 mm.; 86.92, C6303, (4) 85–270 mm.; 90.45, H6105, (1) 218 mm.; 90.48a, H6105, (1) 111 mm.; 120.90, H6204, (1) 186 mm.

B. macristius and *B. panamensis*, both described as new species from the Gulf of Panama by Regan and Trewavas (1929:26–27), are synonymous (R. H. Gibbs, personal communication). According to specimens taken by this survey and in the collections of Scripps Institution of Oceanography, *B. panamensis* ranges at least from the Gulf of Panama to SSE. of Point Conception, Calif.

CHAULIODONTIDAE

58. *Chauliodus macouni* Bean.

Figures 15D and 17.

60.60, H6204, (5) 27.5–184 mm.; 60.80, H6204, (1) 39 mm.; 60.80, C6208, (1) 120 mm.; 60.90, C6208, (1) 68 mm.; 60.100, H6204, (2) 36–53 mm.; 60.140, H6204, (1) 36 mm.; 80.55, H6204, (3) 32–127 mm.; 80.70, H6204, (1) 26 mm.; 80.70, C6208, (1) dis.; 80.90, H6204, (2) 35.5–36 mm.; 80.100, H6204, (1) 81 mm.; 83.77, C6303, (3) 32–36 mm.; 83.90, C6303, (4) 51–64 mm.; 84.67, C6303, (1) 32.5 mm.; 84.70, C6303, (3) 33–198 mm.; 86.92, C6303, (5) 162–213 mm.; 87.80, C6303, (7) 169–204 mm.; 87.90, C6303, (5) 184–207 mm.; 90.60, H6204, (1) 40 mm.; 90.110, C6303, (2) 162–171 mm.

The genus *Chauliodus* has been revised by Regan and Trewavas (1929), Ege (1948), and Morrow (1961). Only two species of *Chauliodus* are known in the eastern Pacific. *C. barbatus* Garman ranges from Peru (Morrow, 1961:270) northward to about 1,770 km. (1,100 miles) SE. of southern Baja California (lat. 13°01' N., long 127°11' W., SIO 60–215). *C. macouni* ranges from Japan, the southern part of the Bering Sea, and through the Gulf of Alaska (Morrow, 1961:275–276) southward to the offshore waters of northern Baja California (station 90.110, C6303). With one exception, all evidence points to a geographic separation of these two species, about 1,770 km. (1,100 miles) separating their known ranges.

The one exception is a single specimen recorded by Ege (1948:108) as *C. macouni* from lat. 0°18'

S., long. 99°07' W., near the Galapagos Island. Ege also reported three specimens of *C. barbatus* from the same station (3558). Morrow (1961: 256), on the basis of a partial reexamination of the excepted specimen, stated that "the Dana specimen of *C. macouni* does not appear to have been mis-identified." Yet nowhere is this specimen so adequately described, or compared with specimens from the usual range of *C. macouni*, that it can confidently be considered to be *C. macouni*, in view of the known occurrence of all other specimens of *C. macouni*.

Regan and Trewavas (1929:32 and 34) stated that in *C. sloani* Bloch and Schneider and in *C. danae* Regan and Trewavas the proportion of the eye diameter into the length of the lower jaw is "larger in male than female." We have determined that external morphological sexual dimorphism exists in *C. macouni*. Of 20 of the larger specimens taken on cruise C6303 (stations 84.70, 86.92, 87.80, 89.90, and 90.110), 8 are females with large ovarian eggs, ranging from 183–207 mm. SL (mean size 197), and 12 are males, 162–202 mm. (mean 177). The males have larger eyes than the females (eye into head 3.3 to 3.8 in the males, 4.0 to 4.6 in the females). One of the most pronounced differences between the sexes is the relative size and shape of the postocular organ. Morrow (1961:273) found that in *C. macouni* the

postocular organ was generally elongate and triangular; the exposed luminous portion was triangular or at least pointed behind, while in other species of *Chauliodus* the postocular photophore was round or nearly so. His characterization is descriptive of the postocular organ of male specimens of *C. macouni*, especially of the exposed luminous portion, but in the females the organ is different and more variable than in the males. The organ is always smaller in the adult females. In some females the exposed luminous portion is reduced to a small rounded area, less than one-quarter of the area of that in the adult males; in others it is elongated, probably owing to a differential contraction following preservation of the surrounding tissue (fig. 17).

MALACOSTEIDAE

59. *Aristostomias scintillans* Gilbert.

Figures 16B and 18.

60.60, H6204, (1) 56 mm.; 60.80, C6208, (8) 73–214 mm.; 60.90, C6208, (2) 62–168 mm.; 60.120, H6204, (1) 189 mm.; 60.180, H6204, (1) 55.5 mm.; 70.80b, B6203, (4) 52–64 mm.; 70.80–5N, B6203, (6) 55–70 mm.; 80.90, B6203, (1) 78.5 mm.; 80.90–5N, B6203, (2) 64–67 mm.; 83.77, C6303, (1) 92 mm.; 86.92, C6303, (1) 54 mm.; 88.105a, B6303, (1) 58 mm.; 90.70, C6208, (1) 148 mm.; 90.80, C6208, (1) 51.5 mm.; 97.40, C6303, (4) 44–140 mm.; 97.50, B6203, (2) 82–129 mm.; 100.40, H6204, (1) 114 mm.; 108.63, C6303, (2) 46–109 mm.; 110.40, H6204, (1) 123 mm.; 120.80, H6204, (1) 101 mm.

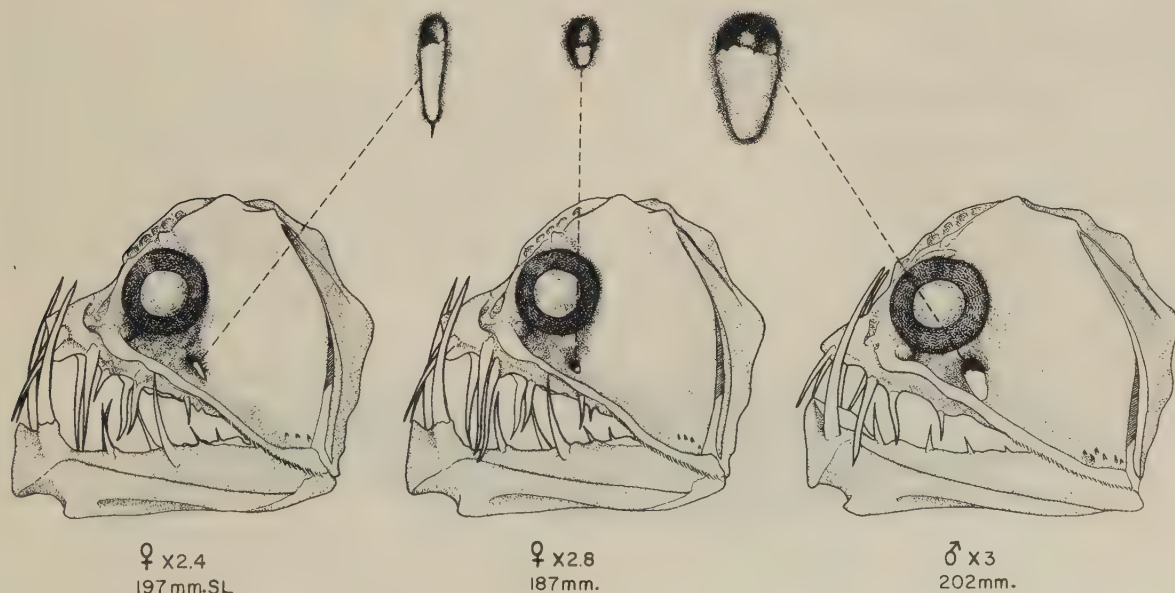


FIGURE 17.—*Chauliodus macouni*, postocular organs, showing the typical triangular shape in juveniles and adult males (right) and the variable and frequently elongated shape in adult females (left and middle).

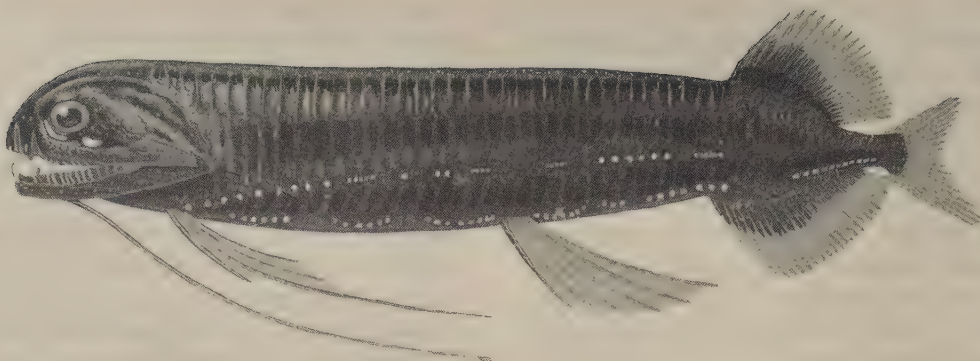


FIGURE 18.—*Aristostomias scintillans*, adult, ca. 280 mm. SL, station 20.40, B5003.

BATHYLACONIDAE

60. *Bathylaco nigricans* Goode and Bean.

Figure 19.

86.92, C6303, (1) 244 mm.

The four previously known specimens of this rare isospondylid (including *Macromastax gym-nus* Beebe) were compared by Maul (1959:1-8). G. E. Maul has lent us another specimen taken off Madeira. Of the six specimens known to us, four are from the North Atlantic, and the other Eastern Pacific specimen is from off Colombia. The two Pacific specimens differ slightly from the Atlantic specimens, but all appear to be conspecific. The specimen taken with the *Cobb* trawl from about 305 km. (190 miles) SSW. off Point Conception, Calif., is the largest known.

GIGANTUROIDEA

GIGANTURIDAE

61. *Bathyleptus lisae* Walters.

Figures 20 and 25C.

86.92, C6303, (1) 182 mm.



FIGURE 19.—*Bathylaco nigricans*, 244 mm. SL, station 86.92, C6303.

This is one of the larger and better preserved specimens of this species that has been taken (V. Walters, personal communication). Alive when it came on deck in the trawl, it bit the junior author on the finger. Despite a number of trenchant morphological differences (that may have an ontogenetic basis), there are certain similarities between this species and *Rosaura rotunda* Tucker that suggest that they may have at least an intra-subordinal relationship.

LYOMERI

MONOGNATHIDAE

62. *Monognathus* sp.

60.140, H6204, (1) 51.5 mm.

This specimen, from about 630 km. (390 miles) WSW. of San Francisco, Calif., is probably one of the largest specimens of this little known group to be recorded; the intrageneric relationships are uncertain, and this specimen is therefore best not identified to species (G. L. Orton and R. H. Rosenblatt, personal communications).

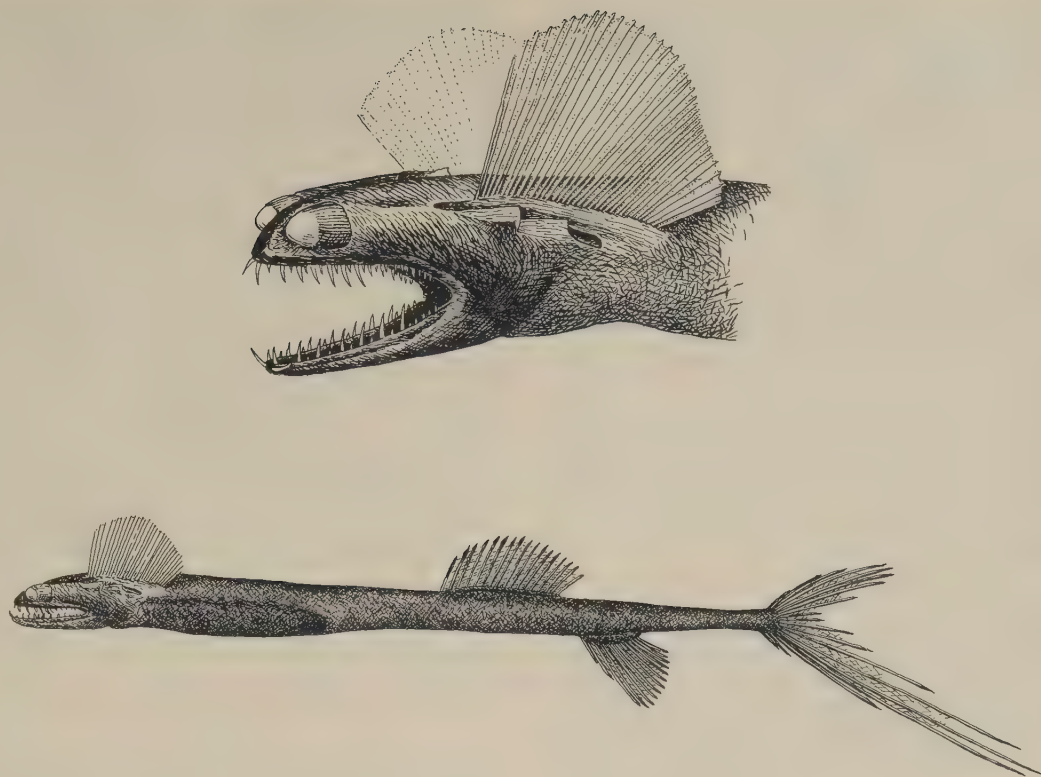


FIGURE 20.—*Bathyleptus lisae* (head and lateral views), 182 mm. SL, station 86.92, C6303.

CETUNCULI

CETOMIMIDAE

63. *Ditropichthys* sp.

90.200, H6204, (1) 38.5 mm.

This specimen, from about 1,000 km. (620 miles) WSW. off Point Conception, Calif., is identified as an undescribed species of *Ditropichthys* by R. R. Rofen (personal communication), who is preparing a detailed description for publication.

INIOMI

NEOSCOPELIDAE

64. *Scopelengys tristis* Alcock.

86.92, C6303, (1) 182 mm.; 90.45a, H6105, (2) 115–143 mm.; 120.50, H6204, (1) 103 mm.

These specimens were taken about 305 km. (190 miles) SE. of Point Conception, about 95 km. (60 miles) SE. of San Pedro, Calif., and about 70 km. (45 miles) W. of Punta Eugenia, Baja California.

MYCTOPHIDAE

65. *Hierops crockeri* (Bolin).

Figure 16C.

60.60, H6204, (1) 29 mm.; 60.70, H6204, (11) 24–35 mm.; 60.70, C6208, (7) 30–36.5 mm.; 60.80, H6204, (8) 22–39 mm.; 60.80, C6208, (2) 35–36 mm.; 60.90, H6204, (16) 15–40 mm.; 60.100, H6204, (3) 23–27 mm.; 60.100, C6208, (1) 38 mm.; 60.120, B6203, (4) 22–38 mm.; 60.120, H6204, (5) 34–38 mm.; 60.140, H6204, (3) 21.5–37 mm.; 60.160, H6204, (4) 34–39 mm.; 60.180, H6204, (1) 24 mm.; 60.200, B6203, (1) 30 mm.; 60.200, H6204, (1) 22 mm.; 70.60, C6208, (2) 22–37 mm.; 70.100, C6208, (2) 36–39 mm.; 80.60, C6208, (2) 23.5–38 mm.; 80.70, B6203, (1) 27 mm.; 80.70, H6204, (3) 10–27 mm.; 80.70, C6208, (1) 19 mm.; 80.75, B6303, (1) 15.3 mm.; 80.80, H6204, (6) 26–42 mm.; 80.100, H6204, (2) 15–16 mm.; 80.140, C6208, (4) 27–46 mm.; 80.150, C6208, (6) 30–52 mm.; 80.170, C6208, (2) 39–45 mm.; 80.180, C6208, (2) 39 mm.; 80.190, C6208, (1) 24 mm.; 80.200, C6208, (1) 45 mm.; 83.77, C6303, (26) 25–36 mm.; 83.90, C6303, (79) 25–39 mm.; 84.67, C6303, (11) 15–36 mm.; 84.68, C6303, (6) 26–35.5 mm.; 86.92, C6303, (4) 27.8–34.5 mm.; 87.80, C6303, (2) 19–28 mm.; 90.45, H6204, (1) 35.5 mm.; 90.48a, H6105, (1) 18.5 mm.; 90.48b, H6105, (5) 12.5–14 mm.; 90.60, C6208, (2) 26–28 mm.; 90.70, H6204, (2) 35–42 mm.; 90.100, C6208, (2) 19–23.5 mm.; 90.140, C6208, (2) 20–46 mm.;

90.160, C6208, (3) 31-40 mm.; 90.180, C6208, (3) 34-43 mm.; 90.200, C6208, (3) 33-40 mm.; 93.31, C6303, (1) 18.5 mm.; 94.32a, B6204, (1) 26 mm.; 97.40, C6303, (2) 17.5-21 mm.; 97.50, B6203, (2) 29-dis., mm.; 97.65, C6303, (4) 31-45 mm.; 100.60, H6204, (1) 25 mm.; 100.65, C6303, (6) 26.5-32.5 mm.; 100.80, H6204, (1) 17.5 mm.; 100.90, H6204, (1) 27.5 mm.; 100.120, H6204, (1) 49 mm.; 100.160, H6204, (1) 45 mm.; 103.50, C6303, (4) 20-23 mm.; 108.63, C6303, (2) 23-43.5 mm.; 110.100, H6204, (1) 15 mm.; 110.140, H6204, (2) 31-44 mm.; 110.160, H6204, (1) 45 mm.; 120.60, H6204, (5) 18.5-26 mm.; 120.70, H6204, (1) 43 mm.; 120.80, H6204, (12) 20-46 mm.; 120.90, M6204, (3) 29-32 mm.

66. *Electrona rissoi* (Cocco).

Figure 16C.

80.150, C6208, (1) 30 mm.; 84.92, B6303, (1) 43.5 mm.; 90.100, C6208, (1) 58.5 mm.; 100.65, C6303, (3) 44.5-45.5 mm.; 110.140, H6204, (1) 48 mm.

67. *Hygophum* sp.

Figure 16D.

60.180, H6204, (1) 43 mm.; 60.200a, B6203, (5) 33-44 mm.; 73.200, B6203, (1) 45 mm.; 80.160, C6208, (246) 19-52.5 mm.; 80.170, C6208, (11) 30-47 mm.; 80.190, C6208, (28) 43-52 mm.; 80.200, C6208, (8) 39-53 mm.; 83.77, C6303, (1) 34 mm.; 86.92, C6303, (1) 36 mm.; 90.80, C6208, (3) 41-44 mm.; 90.90, C6303, (2) 37.5-39.5 mm.; 90.100, C6208, (2) 42 mm.; 90.110, B6203, (1) 42 mm.; 90.120, C6208, (86) 32-51 mm.; 90.140, C6208, (1) 40 mm.; 90.150, C6208, (40) 35-49 mm.; 90.160, H6204, (1) 26 mm.; 90.160, C6208, (10) 33.5-52 mm.; 90.190, C6208, (26) 41-55 mm.; 90.200, H6204, (3) 16-32 mm.; 92.115, B6303, (6) 24.5-40 mm.; 100.65, C6303, (1) 21.5 mm.; 100.100, H6204, (2) 37-43 mm.; 100.140, H6204, (3) 27-43 mm.; 100.160, H6204, (1) 13 mm.; 120.80, H6204, (1) 59 mm.; 123.45, B6212, (1) 45 mm.; 127.45, B6212, (1) 31.5 mm.

Taxonomic differentiation of the species in this genus is not definitive or convincing. Fraser-Brunner (1949:1050) synonymized *H. atratum* (Garman) with *H. reinhardti* (Lütken). There are indications, from other studies, that these two species are distinct (E. H. Ahlstrom, personal communication). The above specimens appear to represent either one or both of the cited nominal species.

68. *Benthoosema suborbitale* (Gilbert).

90.160, H6204, (1) 31 mm.

This specimen was taken about 740 km. (460 miles) SE. of Point Conception, Calif.

69. *Diogenichthys atlanticus* (Tåning).

Figure 21A.

60.80, H6204, (1) 19 mm.; 60.160, B6203, (2) 27 mm.; 60.180, H6204, (6) 15-24 mm.; 60.200a, B6203, (3) 19-26

mm.; 60.200b, B6203, (4) 19.5-23.5 mm.; 70.80b, B6203, (1) 20 mm.; 70.80-5N, B6203, (8) 15-25 mm.; 70.200, H6204, (6) 9-22 mm.; 73.200, B6203, (2) 23-26 mm.; 80.80, C6208, (1) 18 mm.; 80.90, B6203, (1) 23 mm.; 80.90-5N, B6203, (55) 18-25 mm.; 80.90, H6204, (4) 13-22 mm.; 80.160, C6208, (7) all ca. 16 mm.; 80.190, C6208, (4) 16.5-20.5 mm.; 84.92, C6303, (1) 22.5 mm.; 90.48a, H6105, (1) 23 mm.; 90.80, C6208, (5) 20-23 mm.; 90.110, C6303, (3) 21-23.5 mm.; 90.120, H6204, (2) 22 mm.; 90.150, C6208, (1) 23 mm.; 90.160, H6204, (3) all 15 mm.; 90.190, C6208, (1) 20 mm.; 90.200, H6204, (5) 12-16.5 mm.; 100.60, H6204, (2) 22.5-25 mm.; 100.65, C6303, (4) 19.6-23.6 mm.; 100.80, H6204, (3) all 20 mm.; 100.100, H6204, (4) 22-24.5 mm.; 100.140, H6204 (10) 15-23 mm.; 100.160, H6204, (3) all 13 mm.; 110.120, H6204, (1) 16 mm.; 110.160, H6204, (1) 14.5 mm.

The records of capture shown on the chart suggest that *D. atlanticus* is a northern species in this area and *D. laternatus* is a southern species. Records from other collections show that in waters farther offshore than sampled by the survey, the distribution of *D. atlanticus* extends southward at least to lat. 20° N.

70. *Diogenichthys laternatus* (Garman).

Figure 21A.

120.70, H6204, (3) 23.5-24 mm.; 120.80, H6204, (2) 22.5-25 mm.; 120.90, H6204, (6) 22-25 mm.; 127.45, B6212, (1) 14 mm.; 130.40, B6212, (5) 16-25 mm.; 133.35, B6212, (1) 18.5 mm.; 137.35, B6212, (2) 13-18 mm.; 137.50, B6203, (6) 14.5-26 mm.; 140.35, B6212, (16) 12.1-24 mm.

71. *Symbolophorus californiense* (Eigenmann and Eigenmann).

Figure 21B.

60.80, C6208, (4) 60-95 mm.; 60.120, B6203, (4) 29-90 mm.; 60.160, B6203, (1) 32 mm.; 60.160, H6204, (1) 95 mm.; 66.100, C6208, (12) 48-71 mm.; 70.60, C6208, (4) 55-74 mm.; 70.80-5N, B6203, (9) 45-67 mm.; 70.80, C6208, (167) 39-91 mm.; 70.100, C6208, (1) 70 mm.; 80.52, C6208, (1) 75 mm.; 80.55, H6204, (1) 90 mm.; 80.60, H6204, (1) 73 mm.; 80.60, C6208, (7) 71-86 mm.; 80.65, B6303, (12) 42-94 mm.; 80.70, C6208, (2) 78-81 mm.; 80.75, B6203, (6) 27-59 mm.; 80.80, H6204, (2) 52-67 mm.; 80.80, C6208, (6) 53-73 mm.; 80.90, B6203, (4) 43-76 mm.; 80.90-5N, B6203, (5) 25-59 mm.; 80.90, H6204, (4) 32-67 mm.; 80.100, B6203, (34) 44-94 mm.; 80.200, C6208, (1) 30.5 mm.; 82.69, C6303, (24) 37.5-90 mm.; 83.77, C6303, (124) 32.5-85 mm.; 83.70b, B6303, (16) 51-95 mm.; 83.90, C6303, (2) 56-66 mm.; 83.70, C6303, (7) 53-70.5 mm.; 84.67, C6303, (3) 56.5-65.5 mm.; 84.92, B6303, (10) 39.5-90 mm.; 84.70, C6303, (28) 48-75 mm.; 86.92, C6303, (1) 57 mm.; 87.80, C6303, (2) 52.5-55.5 mm.; 87.90, C6303, (5) 46.5-64.5 mm.; 90.48a, H6105, (3) 57-77 mm.; 90.60, H6204, (1) 65 mm.; 90.70, C6208, (2) 66-70 mm.; 90.80, C6208, (5) 40-63 mm.; 90.90, C6303, (1) 73 mm.; 90.120, C6208, (5) 28-29.5 mm.; 90.190, C6208, (1) 27 mm.; 91.39a,

C6208, (4) 37.5–67 mm.; 91.39b, C6208, (3) 65–77.5 mm.; 97.40, C6303, (11) 48–86 mm.; 97.50, B6203, (4) 54–70 mm.; 97.65, C6303, (24) 32.5–51.5 mm.; 100.40, H6204, (1) 51 mm.; 100.60, H6204, (2) 24–60 mm.; 100.65, C6303, (86) 28–87.5 mm.; 100.90, H6204, (1) 28 mm.; 100.120, H6204, (1) 24 mm.; 103.50, C6303, (1) 54 mm.; 107.60, C6303, (21) 47–66 mm.; 108.63, C6303, (6) 49.5–62.5 mm.; 110.50, B6203, (1) 46 mm.

This species has generally been known as *Myctophum californiense*. It was designated as the type species of the new genus *Symbolophorus* by Bolin and Wisner in Bolin (1959:11).

72. *Myctophum nitidulum* Garman.

Figure 21B.

60.200a, B6203, (1) 65 mm.; 90.150, C6208, (2) 50–68 mm.; 90.200, H6204, (1) 19 mm.; 100.65, C6303, (13) 48–63 mm.; 108.63, C6303, (1) 70 mm.; 110.120, H6204, (2) 25 mm.; 123.50, B6203, (2) 26–36 mm.

This species was recently synonymized with *M. margaritatum* Gilbert, the name by which it has been more commonly known, and was distinguished from *M. affine* (Lütken) by Bolin (1959:14).

73. *Gonichthys tenuiculus* (Garman).

130.40, B6212, (1) 28 mm.; 137.50, B6203, (1) 44 mm.

These specimens were taken about 70 km. (45 miles) SW. of Ballenas Bay and about 160 km. (100 miles) W. of Santa Maria Bay, Baja California.

74. *Tarletonbeania crenularis* (Jordan and Gilbert).

Figure 16D.

60.60, H6204, (8) 12–62 mm.; 60.60, C6208, (7) 38–59 mm.; 60.70, H6204, (6) 22–35 mm.; 60.70, C6208, (3) 43–64 mm.; 60.80, H6204, (8) 12.5–32 mm.; 60.80, C6208, (9) 29–54 mm.; 60.90, H6204, (4) 23–31 mm.; 60.90, C6208, (2) 17–36 mm.; 60.100, H6204, (4) 13–31 mm.; 60.100, C6208, (3) 15–29 mm.; 60.120, B6203, (2) 26–30 mm.; 60.180, H6204, (3) all 15 mm.; 65.54, C6208, (8) 37–74 mm.; 70.51, C6208, (1) 44 mm.; 70.60, C6208, (1) 17 mm.; 70.80–5N, B6203, (1) 24 mm.; 77.51, C6208, (3) 34.5–45 mm.; 80.52, C6208, (77) 34–80 mm.; 80.55, H6204, (1) 32 mm.; 80.60, B6203, (1) 31 mm.; 80.60, H6204, (2) 30–31 mm.; 80.60, C6208, (8) 34–60 mm.; 80.65, B6303, (7) 28–36.5 mm.; 80.70, C6208, (2) 19 mm.; 80.75, B6303, (1) 27 mm.; 80.80, C6208, (1) 26 mm.; 80.90–5N, B6203, (3) 27–29 mm.; 80.90, H6204, (3) 17–34 mm.; 80.100, B6203, (1) 36 mm.; 80.100, H6204, (1) 16.5 mm.; 83.69, C6303, (43) 32.5–68 mm.; 83.70a, B6303, (2) 23–28 mm.; 83.70b, B6303, (3) 30.5–32.5 mm.; 83.77, C6303, (2) 18–50 mm.; 83.90, C6303, (15) 19.5–30.5 mm.; 84.67, C6303, (29) 37.5–61 mm.; 84.70, C6303, (16) 37.5–66.5 mm.; 84.92, B6303, (3) 14–26 mm.; 90.35, B6203, (1) 43 mm.; 90.45a, H6105, (1)

14.5 mm.; 90.45, H6204, (1) 29 mm.; 90.48a, H6105, (7) 16–32.5 mm.; 90.48b, H6105, (1) 14.5 mm.; 90.60, H6204, (8) 33–48 mm.; 90.70, C6208, (1) 28 mm.

75. *Lobianchia gemellari* (Cocco).

Fig 21D.

90.160, C6208, (5) 50–53 mm.; 90.200, C6208, (1) 31 mm.; 100.160, H6204, (1) 57 mm.

This species was listed as *Diaphus (Hyperphophs) gemellari* (Cocco) by Fraser-Brunner (1949:1066). It was reestablished as the type species of the genus *Lobianchia* Gatti by Bolin (1959:18). Taken some 800 km. (500 miles) WSW. of San Diego, these records would appear to approach the limit of its eastward distribution in this latitude.

76. *Diaphus theta* Eigenmann and Eigenmann.

Figure 21C.

60.60, H6204, (27) 24–53 mm.; 60.60, C6208, (13) 37–42 mm.; 60.70, H6204, (251) 28–40 mm.; 60.70, C6208, (8) 34–45 mm.; 60.80, H6204, (11) 25–71 mm.; 60.80, C6208, (34) 34–54 mm.; 60.90, H6204, (9) 29–63 mm.; 60.90, C6208, (8) 37–41 mm.; 60.100, H6204, (6) 30–63 mm.; 60.100, C6208, (1) 41 mm.; 60.120, B6203, (5) 32–66 mm.; 60.120, H6204, (2) 30–47 mm.; 60.160, H6204, (1) 56 mm.; 70.51, C6208, (12) 37.5–57 mm.; 70.80b, B6203, (4) 33–64 mm.; 70.80–5N, B6203, (38) 24–41 mm.; 70.80, C6208, (15) 32–48 mm.; 70.90, B6203, (1) 32 mm.; 79.54, B6303, (3) 30–52 mm.; 80.52, C6208, (2) 36–40 mm.; 80.55, H6204, (2) 29–31 mm.; 80.60, B6203, (2) 32–34 mm.; 80.60, H6204, (5) 25–34 mm.; 80.60, C6208, (16) 33–54 mm.; 80.70, B6203, (1) 26 mm.; 80.70, H6204, (1) 33 mm.; 80.70, C6208, (5) 37–44 mm.; 80.75, B6303, (8) 26–59 mm.; 80.80, H6204, (5) 27–67 mm.; 80.80, C6208, (22) 15–60 mm.; 80.90, B6203, (1) 55 mm.; 80.90–5N, B6203, (6) 22–39 mm.; 80.90, H6204, (3) 26–50 mm.; 82.69, C6303, (15) 26–57.5 mm.; 83.70a, B6303, (17) 29–60 mm.; 83.70b, B6303, (2) 135–53 mm.; 83.77, C6303, (45) 24–51 mm.; 83.90, C6303, (63) 22–56.5 mm.; 83.70, C6303, (11) 27–57.5 mm.; 84.67, C6303, (206) 24–50 mm.; 84.68, C6303, (70) 26.5–41.5 mm.; 84.70, C6303, (74) 23–50 mm.; 84.92, B6303, (1) 30 mm.; 87.80, C6303, (1) 26.5 mm.; 88.105b, B6303, (6) 21–24.5 mm.; 90.32, B6203, (16) 24–34 mm.; 90.32, H6204, (2) 27–31 mm.; 90.45, H6204, (3) 35–53 mm.; 90.47, C6208, (13) 35–40 mm.; 90.48a, H6105, (3) 34–39 mm.; 93.31, C6303, (5) 21–28.5 mm.; 97.40, C6303, (6) 23–29 mm.; 97.50, B6203, (2) 26–58 mm.; 97.65, C6303, (1) 29 mm.; 100.65, C6303, (1) 23 mm.; 100.120, H6204, (1) 33 mm.; 100.160, H6204, (1) 30 mm. (specimen damaged, identification questionable).

77. *Diaphus fulgens* Brauer.

Figure 21C.

60.200a, B6203, (1) 36 mm.; 87.200, B6203, (1) 30 mm.; 90.150, C6208, (2) 42 mm.; 90.200, C6208, (1) 38 mm.; 110.160, H6204, (3) 28.5–43 mm.



FIGURE 21.—Locations of capture of: A, *Diogenichthys atlanticus*, *Diogenichthys laternatus*. B, *Symbolophorus californiense*, *Myctophum nitidulum*. C, *Diaphus theta*, *Diaphus fulgens*, *Diaphus protoculus*. D, *Lobianchia gemellari*, *Diaphus andersoni?*, *Aethoprora elucens*.

These specimens and those of *D. protoculus* (following) were identified according to Fraser-Brunner (1949:1075). The differences between the two forms are slight, however, and *D. fulgens* may be a junior synonym of *D. protoculus*.

78. *Diaphus protoculus* Gilbert.

Figure 21C.

80.200, C6208, (1) 36.5 mm.; 90.160, C6208, (8) 31.5-43 mm.; 90.180, B6203, (1) 24 mm.; 90.190, C6208, (1) 37 mm.; 90.200, H6204, (1) 27 mm.; 110.140, H6204, (2) 43 mm.

79. *Diaphus andersoni* Tåning?

Figure 21D.

60.120, B6203, (21) 23-33 mm.; 60.120, H6204, (1) 30 mm.; 60.160, B6203, (1) 35 mm.; 60.180, H6204, (1) 25 mm.; 60.200, H6204, (1) 28 mm.; 73.200, B6203, (2) 25-28 mm.; 80.190, C6208, (1) 32 mm.; 80.200, C6208, (2) 26-29 mm.; 87.200, B6203, (1) 27 mm.; 90.140, C6208, (1) 27.5 mm.; 90.160, H6204, (1) 27 mm.; 90.160, C6208, (3) 26-30.5 mm.; 90.180, B6203, (3) 25-27 mm.; 90.180, H6204, (2) 29 mm.; 100.160, H6204, (3) 26.5-30.5 mm.; 110.140, H6204, (1) 30 mm.

D. andersoni had previously been recorded only from the South Pacific. The above specimens are obviously closely related to *D. andersoni*, but certain slight differences, especially the relative length of the luminous patch of tissue extending back from the lateral pectoral photophore (PLO), suggest that they may be distinct (R. L. Wisner, personal communication). If these differences warrant specific distinction of the above specimens from *D. andersoni*, then these specimens represent an undescribed species.

80. *Aethoprora elucens* (Brauer).

Figure 21D.

80.200, C6208, (1) 51 mm.

This species was listed as *Diaphus* (*Lamprossa*) *elucens* Brauer by Fraser-Brunner (1949:1073). It was later placed in the genus *Aethoprora* Goode and Bean by Bolin (1959:22). This single record from about 970 km. (600 miles) off Point Conception undoubtedly represents a rare occurrence of the species off California.

81. *Notolychnus valdiviae* (Brauer).

Figure 22A.

60.180, H6204, (4) 20-24 mm.; 60.200a, B6203, (14) all ca. 14 mm.; 60.200, H6204, (3) 22-24 mm.; 70.200, H6204, (11) 17-25 mm.; 73.200, B6203, (67) 14-26 mm.; 80.200, C6208, (1) 22.5 mm.; 84.92, B6303, (2) 22-25 mm.; 87.200, B6203, (9) 18-26 mm.; 90.120, C6208, (2) 14.5-18.5 mm.;

90.160, H6204, (9) 18-25 mm.; 90.180, H6204, (2) 24-26 mm.; 90.200, H6204, (7) 20-24 mm.; 100.60, H6204, (1) 19 mm.; 100.80, H6204, (2) 23 mm.; 100.100, H6204, (1) 22 mm.; 100.140, H6204, (20) 19.5-24.5 mm.; 100.160, H6204, (24) 13-24 mm.; 110.160, H6204, (16) 20-30 mm.

82. *Lampadena urophaios* Paxton.

Figure 22B.

60.160, H6204, (1) 57 mm.; 86.92, C6303, (1) 50 mm.; 100.40, H6204, (1) 103 mm.

These specimens extend northward and seaward, the known range of this species recently described by Paxton (1963:29-33).

83. *Taaningichthys bathyphilus* (Tåning).

Figure 22B.

120.70, H6204, (1) 66.5 mm.

This species, previously known as *Lampadena bathyphila*, was designated as the type species of the new genus *Taaningichthys* by Bolin (1959:25).

84. *Taaningichthys minimus* (Tåning).

Figure 22B.

80.200, C6208, (1) 52 mm.; 100.140, H6204, (1) 55 mm.

This species, formerly known as *Lampadena minima*, was one of the two species included in the new genus *Taaningichthys* described by Bolin (1959:25). *T. minimus* was described from the North Atlantic Ocean—we know of no previous records of it from the Pacific Ocean.

85. *Taaningichthys* spp.

Figure 22B.

60.60, H6204, (1) 90 mm.; 60.140, H6204, (2) 80-85 mm.; 80.90, H6204, (1) 30 mm.; 100.60, H6204, (1) 70 mm.; 100.80, H6204, (1) 83 mm.; 110.160, H6204, (1) 51 mm.

The above six station records include more than one species of *Taaningichthys*. They are not, so far as known, *T. bathyphilus* or *T. minimus*, the only two species ascribed to this genus by Bolin (1959:25). Some of the above specimens lack photophores, and all of them may represent undescribed species.

86. *Stenobranchius leucopsarus* (Eigenmann and Eigenmann).

Figure 22A.

60.60, H6204, (95) 19-70 mm.; 60.70, H6204, (4) 20-26 mm.; 60.80, H6204, (20) 15.5-82 mm.; 60.80, C6208, (26) 25-63 mm.; 60.90, H6204, (10) 29-56 mm.; 60.90, C6208, (1) 51 mm.; 60.100, H6204, (1) 35 mm.; 60.120, H6204, (1) 38 mm.; 70.80b, B6203, (4) 33-64 mm.; 70.80-5N, B6203, (57) 26-60 mm.; 77.51, C6208, (6) 50-66 mm.; 79.54, B6303,

(8) 35.5–53 mm.; 80.52, C6208, (3) 49–52 mm.; 80.55, H6204, (117) 32–82 mm.; 80.60, B6203, (13) 33–57 mm.; 80.60, H6204, (154) 30–75 mm.; 80.60, C6208, (735) 22.5–78 mm.; 80.65, B6303, (4) 28–69 mm.; 80.70, H6204, (3) 36–71 mm.; 80.70, C6208, (24) 43–70 mm.; 80.75, B6303, (4) 34.5–71.5 mm.; 80.80, H6204, (8) 34–78 mm.; 80.90, B6203, (5) 38–60 mm.; 80.90–5N, B6203, (11) 31–51 mm.; 80.90, H6204, (4) 17–35 mm.; 80.100, B6203, (2) 32–36 mm.; 82.69, C6303, (38) 29–68.5 mm.; 83.70, C6303, (44) 49–72 mm.; 83.70a, B6303, (4) 57–59 mm.; 83.70b, B6303, (1) 29 mm.; 83.77, C6303, (29) 31–73 mm.; 83.90, C6303, (3) 38–62.5 mm.; 84.67, C6303, (43) 44–71 mm.; 84.70, C6303, (143) 31–74 mm.; 84.92, B6303, (4) 55–70 mm.; 90.32, B6203, (27) 29–72 mm.; 90.32, H6204, (21) 32–80 mm.; 90.45, H6105, (51) 37–78 mm.; 90.47, C6208, (74) 44–72 mm.; 90.48a, H6105, (135) 10.5–74 mm.; 90.48b, H6105, (4) 10–17.5 mm.; 90.60, H6204, (257) 30–65 mm.; 90.70, H6204, (1) 38 mm.; 90.70, C6208, (10) 42–63 mm.; 93.29, C6208, (1) adult; 94.32a, B6204, (4) 36–69 mm.; 94.32b, B6204, (7) 52–67 mm.; 95.31a, B6204, (8) 33–49 mm.; 95.31b, B6204, (11) 35–66 mm.; 95.31c, B6204, (20) 34–59 mm.; 97.40, C6303, (67) 32–76 mm.; 97.50, B6203, (1) 51 mm.; 97.65, C6303, (3) 50–63 mm.; 100.40, H6204, (12) 39–72 mm.; 100.65, C6303, (12) 49.5–62 mm.

This species has usually been recorded as *Lampanyctus leucopsarus*, although it was recorded as *Lampanyctus* (*Stenobrachius*) *leucopsarus* by Fraser-Brunner (1949:1082). *Stenobrachius* is distinctive enough to warrant full generic status (R. L. Wisner, personal communication).

87. *Lampanyctus* (*Triphoturus*) *mexicanus* (Gilbert).

Figure 22C.

60.60, H6204, (1) 35 mm.; 80.55, H6204, (2) 34–55 mm.; 80.60, H6204, (3) 35–47 mm.; 80.65, B6303, (1) 23 mm.; 80.70, H6204, (4) 28–57 mm.; 80.75, B6303, (1) 24.5 mm.; 80.80, H6204, (3) 27–62 mm.; 80.80, C6208, (2) 37–43 mm.; 80.90–5N, B6203, (13) 26–58 mm.; 80.90, H6204, (12) 24–60 mm.; 80.100, B6203, (1) 48 mm.; 82.69, C6303, (29) 22–61.5 mm.; 83.70a, B6303, (1) 23.5 mm.; 83.70b, B6303, (3) 28–29 mm.; 83.77, C6303, (84) 24–67.5 mm.; 84.67, C6303, (1) 44 mm.; 84.92, B6303, (1) 50 mm.; 86.92, C6303, (93) 44–67 mm.; 87.80, C6303, (58) 38.5–66.5 mm.; 87.90, C6303, (1) 43.5 mm.; 90.32, B6203, (10) 32–58 mm.; 90.32, H6204, (11) 28–49 mm.; 90.45, H6105, (35) 29–54 mm.; 90.45, H6204, (1) 29 mm.; 90.47, C6208, (3) 42–60 mm.; 90.48a, H6105, (79) 14–66 mm.; 90.60, B6203, (1) 24 mm.; 90.60, H6204, (10) 30–59 mm.; 90.70, C6208, (2) 47–54 mm.; 90.120, H6204, (1) 27 mm.; 90.160, H6204, (1) 56 mm.; 91.39a, C6208, (1) 43 mm.; 93.100, C6303, (3000) 25–70 mm.; 94.32a, B6204, (14) 30–57 mm.; 95.31b, B6204, (2) 31–34 mm.; 97.40, C6303, (715) 23–66 mm.; 97.50, B6203, (5) 29–57 mm.; 97.65, C6303, (20) 26–66 mm.; 100.40, H6204, (20) 38–65 mm.; 100.40, C6303, (2) 54 mm.; 100.50, H6204, (1) 60 mm.; 100.60, H6204, (22) 30–66 mm.; 100.65, C6303, (461) 22.5–67 mm.; 100.80, H6204, (3) 27–60 mm.; 100.90, H6204, (17) 52–71 mm.;

100.100, H6204, (7) 23–63 mm.; 100.120, H6204, (1) 58 mm.; 100.140, H6204, (5) 31.5–58.5 mm.; 107.60, C6303, (1) 37 mm.; 108.63, C6303, (1857) 24–72 mm.; 110.35, H6204, (11) 35–66 mm.; 110.40, H6204, (83) 28.5–70 mm.; 110.46, C6303, (2) 47.5 mm.; 110.50, B6203, (22) 23–69 mm.; 110.120, H6204, (13) 24–67 mm.; 110.160, H6204, (1) 28 mm.; 111.36a, C6303, (ca. 600) adults and juveniles; 111.37b, C6303, (101) 32–62 mm.; 113.34a, C6303, (29) 25–60 mm.; 118.43, B6212, (613) 16.5–43 mm.; 120.45, H6204, (307) 22–69 mm.; 120.45, B6212, (22) 16.5–56 mm.; 120.50, H6204, (299) 26–68 mm.; 120.60, H6204, (2) 23.5–24 mm.; 120.70, H6204, (33) 25.5–64 mm.; 120.80, H6204, (83) 26.5–66 mm.; 120.90, H6204, (28) 27–65 mm.; 123.45, B6212, (98) 15.5–56 mm.; 123.50, B6203, (135) 23–70 mm.; 127.45, B6212, (48) 17.5–60.5 mm.; 130.40, B6212, (40) 18–56.5 mm.; 133.35, B6212, (20) 17.5–40 mm.; 137.35, B6212, (6) all 20 mm.; 137.50, B6203, (5) 25–59 mm.; 140.35, B6212, (183) 16.5–53 mm.

88. *Lampanyctus* (*Triphoturus*) *nigrescens* Brauer.

Figure 22C.

60.180, H6204, (1) 25 mm.; 60.200, H6204, (1) 28 mm.; 70.200, H6204, (2) 26 mm. and damaged adult; 80.160, C6208, (3) 30–33 mm.; 87.200, C6208, (2) 32–38 mm.; 90.160, C6208, (1) 31 mm.

89. *Lampanyctus* (*Triphoturus*) *microchir* Gilbert.

Figure 22C.

80.200, C6208, (1) 35 mm.

90. *Lampanyctus* *ritteri* Gilbert.

Figure 22D.

60.60, H6204, (6) 38–84 mm.; 60.80, H6204, (9) 30–83 mm.; 60.80, C6208, (35) 43–88 mm.; 60.90, H6204, (5) 35–98 mm.; 60.90, C6208, (2) 42–51 mm.; 60.100, H6204, (6) 29–67 mm.; 60.120, B6203, (13) 28–92 mm.; 60.120, H6204, (12) 43–115 mm.; 60.140, H6204, (8) 20–105 mm.; 60.160, H6204, (4) 36–118 mm.; 70.80b, B6203, (7) 39–44 mm.; 70.80–5N, B6203, (120) 28–57 mm.; 73.200, B6203, (1) 25 mm.; 80.55, H6204, (8) 40–104 mm.; 80.60, B6203, (7) 22–64 mm.; 80.60, H6204, (20) 36–105 mm.; 80.60, C6208, (42) 33–80 mm.; 80.70, H6204, (10) 44–115 mm.; 80.75, B6303, (8) 34–76.5 mm.; 80.80, H6204, (35) 35–109 mm.; 80.90, B6203, (5) 38–60 mm.; 80.90–5N, B6203, (4) 37–44 mm.; 80.90, H6204, (27) 26–96 mm.; 80.100, B6203, (14) 28–70 mm.; 82.69, C6303, (121) 30–84 mm.; 83.70, C6303, (3) 49–72.5 mm.; 83.70a, B6303, (5) 43.5–70 mm.; 83.77, C6303, (259) 28.5–90 mm.; 83.90, C6303, (1) 66 mm.; 84.67, C6303, (36) 31–65.5 mm.; 84.70, C6303, (6) 37–95 mm.; 84.92, B6303, (31) 23–93 mm.; 86.92, C6303, (31) 38–110 mm.; 87.80, C6303, (8) 34–78 mm.; 90.32, B6203, (8) 36–60 mm.; 90.32, H6204, (1) 47 mm.; 90.45a, H6105, (2) 47–107 mm.; 90.47, C6208, (2) 51–73 mm.; 90.48a, H6105, (120) 23.5–97 mm.; 90.60, B6203, (2) 48 mm.; 90.60, H6204, (60) 35–106 mm.; 90.70, H6204, (20) 39–112 mm.; 90.70, C6208, (14) 27.5–70 mm.; 91.39a, C6208, (1) 54 mm.; 93.100, C6303, (8) 82–93 mm.; 94.32a, B6204, (1) 95 mm.; 94.32b, B6204, (2) 66–82 mm.; 97.40, C6303, (88)



FIGURE 22.—Locations of capture of: A, *Notolychnus valdiviae*, *Stenobranchius leucopsarus*. B, *Lampadena urophaos*, *Taaningichthys bathyphilus*, *Taaningichthys sminimus*, *Taaningichthys spp.* C, *Lampanyctus (Triphoturus) mexicanus*, *Lampanyctus (Triphoturus) nigrescens*, *Lampanyctus (Triphoturus) microchir*. D, *Lampanyctus ritteri*, *Lampanyctus niger*.

28-108 mm.; 97.50, B6203, (7) 32-97 mm.; 97.65, C6303, (2) 46 mm.; 100.40, H6204, (12) 48-97 mm.; 100.60, H6204, (6) 28-110 mm.; 100.65, C6303, (47) 27.5-99.5 mm.; 100.90, H6204, (1) 107 mm.; 100.100, H6204, (1) 24.5 mm.; 100.120, H6204, (1) 84 mm.; 108.63, C6303, (15) 28-99 mm.; 110.35, H6204, (1) 30 mm.; 110.40, H6204, (3) 88-105 mm.; 110.50, B6203, (2) 46-90 mm.; 120.45, H6204, (2) 35-115 mm.; 123.50, B6203, (1) 27 mm.; 137.50, B6203, (2) 43 mm.

91. *Lampanyctus regalis* (Gilbert).

Figure 23A.

60.60, H6204, (3) 57-76 mm.; 60.80, C6208, (1) 64 mm.; 60.90, H6204, (2) 50-58 mm.; 60.100, H6204, (1) 36 mm.; 60.120, B6203, (1) 38 mm.; 60.180, H6204, (2) 24-25 mm.; 70.200, H6204, (1) 4.5 mm.; 80.55, H6204, (3) 41-53 mm.; 80.60, B6203, (1) 40 mm.; 80.60, H6204, (2) 42-44 mm.; 80.75, B6303, (2) 27.5-39.5 mm.; 83.69, C6303, (1) 36 mm.; 83.77, C6303, (1) 39 mm.; 84.67, C6203, (1) 43 mm.; 87.200, B6203, (2) 34-35 mm.; 90.32, H6204, (1) 43 mm.; 90.45a, H6105, (2) 48-52 mm.; 90.60, H6203, (1) 35 mm.; 90.160, H6204, (3) 38-49 mm.; 97.50, B6203, (2) 44 mm.; 100.65, C6303, (2) 36-48 mm.; 100.120, H6204, (1) 39 mm.

92. *Lampanyctus idostigma* Parr.

Figure 23A.

120.80, H6204, (1) 44 mm.; 120.90, H6204, (3) 30-59 mm.

93. *Lampanyctus niger* Günther.

Figure 22D.

73.200, B6203, (1) 36 mm.; 80.200, C6208, (1) 42 mm.; 86.92, C6303, (7) 51-88 mm.; 100.65, C6303, (1) 62 mm.; 100.140, H6204, (2) 111 mm.

94. *Lampanyctus niger* Günther?

60.180, H6204, (1) 64 mm.; 87.80, C6303, (2) 72-89 mm.; 100.100, H6204, (1) 44.5 mm.; 100.160, H6204, (1) 102 mm.

These damaged specimens appear to represent this species, but their identity is uncertain.

95. *Lampanyctus steinbecki* Bolin.

Figure 23B.

60.140, H6204, (1) 54 mm.; 60.160, H6204, (1) 77 mm.; 60.180, H6204, (3) 37.5-47.5 mm.; 60.200a, B6203, (2) 39 mm.; 60.200, H6204, (3) 28-112 mm.; 70.200, H6204, (7) 26-53 mm.; 73.200, B6203, (6) 25-42 mm.; 80.200, C6208, (1) 40 mm.; 83.77, C6303, (1) 30.5 mm.; 87.80, C6303, (1) 35.2 mm.; 90.160, H6204, (1) 43.5 mm.; 90.160, C6208, (2) 35-41 mm.; 90.180, B6203, (1) 39 mm.; 90.180, H6204, (12) 35-47 mm.; 90.200, H6204, (3) 28-33 mm.; 100.140, H6204, (3) 25-37 mm.; 110.160, H6204, (6) 23-51 mm.

96. *Lampanyctus tenuiformes* (Brauer).

Figure 23B.

83.77, C6303, (1) 38 mm.; 100.65, C6303, (2) 34-35 mm.

97. *Lampanyctus parvicauda* Parr.

Figure 23B.

137.50, B6203, (1) 60 mm.

This species was distinguished from the closely related *L. omostigma* Gilbert by Wisner (1963: 16-23.)

98. *Lampanyctus* sp. (no pectorals).

Figure 23B.

60.180, H6204, (1) 63 mm.; 60.200, B6203, (3) 30-65 mm.; 60.200, H6204, (3) 56-60 mm.; 70.200, H6204, (2) 23-39 mm.; 73.200, B6203, (3) 57-66 mm.; 80.80, H6204, (1) 61 mm.; 80.100, B6203, (1) 62 mm.; 80.200, C6208, (4) 31.5-62 mm.; 83.77, C6303, (1) 32 mm.; 86.92, C6303, (10) 47.5-60 mm.; 87.80, C6303, (1) damaged adult; 90.32, H6204, (1) 46 mm.; 90.48a, H6105, (1) 30 mm.; 90.70, C6208, (1) 48 mm.; 90.160, H6204, (4) 26-64 mm.; 90.160, C6208, (12) 45-58 mm.; 90.180, H6204, (10) 27-68 mm.; 90.200, H6204, (2) 59-63 mm.; 100.60, H6204, (2) 25-32 mm.; 100.90, H6204, (1) 35 mm.; 100.120, H6204, (1) 55 mm.; 100.140, H6204, (7) 25.5-59 mm.; 100.160, H6204, (4) 49-60 mm.; 110.120, H6204, (1) 50 mm.; 120.90, H6204, (1) 47 mm.

These specimens probably represent an undescribed species. None of them possesses visible pectoral fins, and cleared and stained specimens have no pectoral fin ray bases or actinosts and fewer vertebrae than are usually found in the genus *Lampanyctus*. Pattern and numbers of photophores also reveal certain differences between this form and other members of the genus. They are specifically distinct from the pectoral-less *Lampanyctus achirus* described as a new species by Andriashev (1962: 257-259).

99. *Lampanyctus* sp.

110.160, H6204, (1) 22 mm.

This single specimen, from about 800 km. (500 miles) westward of Punta Eugenia, Baja California, probably represents an undescribed species (R.L. Wisner, personal communication).

100. *Lampanyctus* spp., unidentified.

60.100, H6204, (1) head only; 84.68, C6303, (1) juvenile; 84.92, B6303, (2) juvenile and adult; 90.70, H6204, (3) 52-90 mm.; 90.160, H6204, (1) 20 mm.; 90.190, C6208, (1) 40 mm.; 90.200, H6204, (2) larva and juvenile; 100.50, H6204, (1) 67 mm.; 100.160, H6204, (3) juveniles; 110.35, H6204, (1) 37 mm.; 110.140, H6204, (5) juveniles; 137.50, B6203, (4) 30-35 mm.

These specimens probably represent several species, but they are either too damaged or too immature to allow specific identification without adequate comparative material.



FIGURE 23.—Locations of capture of: A, *Lampanyctus regalis*, *Lampanyctus idostigma*. B, *Lampanyctus* sp. (no pectorals), *Lampanyctus steinbecki*, *Lampanyctus tenuiformes*, *Lampanyctus parvicauda*. C, *Parvilux ingens*, *Lepidophanes pyrsobolus*. D, *Ceratoscopelus townsendi*, *Notoscopelus resplendens*.

101. *Parvilux ingens* Hubbs and Wisner.

Figure 23C.

60.80, C6208, (3) 108–128 mm.; 60.90, H6204, (1) 95 mm.; 60.100, H6204, (1) 74 mm.; 60.120, H6204, (2) 56–96 mm.; 83.77, C6303, (1) 51.5 mm.; 86.92, C6303, (6) 93–178 mm.; 87.80, C6303, (1) 174 mm.; 90.70, C6208, (2) 134–157 mm.; 90.120, H6204, (1) 121 mm.; 97.40, C6303, (2) 52 mm.; 97.50, B6203, (2) 74–76 mm.; 100.40, H6204, (1) 72 mm.; 100.60, H6204, (1) 76 mm.; 100.65, C6303, (4) 139–192 mm.; 110.46, C6303, (1) 166 mm.

102. *Lepidophanes pyrsobolus* (Alcock).

Figure 23C.

60.180, H6204, (1) 25 mm.; 70.200, H6204, (1) 42 mm.; 73.200, B6203, (4) 21–30 mm.; 80.200, C6208, (1) 33.5 mm.; 83.77, C6303, (6) 29.5–42 mm.; 90.70, C6208, (2) 36 mm.; 90.120, H6204, (2) 31–37 mm.; 90.160, H6204, (3) 22–38 mm.; 90.160, C6208, (8) 29–40 mm.; 90.180, H6204, (1) 38 mm.; 90.200, H6204, (2) 30–34 mm.; 100.65, C6303, (6) 30.5–45.5 mm.; 100.80, H6204, (1) 30 mm.; 100.100, H6204, (3) 29.5–31.5 mm.; 100.140, H6204, (5) 22.5–46 mm.; 110.120, H6204, (2) 24–28 mm.; 110.160, H6204, (5) 23–44 mm.; 137.50, B6203, (1) 27 mm.

103. *Ceratoscopelus townsendi* (Eigenmann and Eigenmann).

Figure 23D.

60.80, H6204, (3) 33–55 mm.; 60.100, H6204, (6) 35–60 mm.; 60.120, B6203, (2) 40–56 mm.; 60.120, H6204, (1) 43 mm.; 60.140, H6204, (2) 53 mm.; 60.160, H6204, (2) 72–83 mm.; 60.180, H6204, (2) 31–32 mm.; 60.200, B6203, (1) 25 mm.; 66.100, C6208, (7) 23–35 mm.; 70.80b, B6203, (2) 29–38 mm.; 70.80–5N, B6203, (35) 22–52 mm.; 70.200, H6204, (3) 13–44 mm.; 73.200, B6203, (1) 52 mm.; 80.70, H6204, (1) 52 mm.; 80.75, B6303, (1) 52 mm.; 80.80, H6204, (3) 22–52 mm.; 80.90–5N, B6203, (66) 29–55 mm.; 80.90, H6204, (15) 40–59 mm.; 80.100, B6203, (1) 54 mm.; 80.160, C6208, (1) 22.5 mm.; 80.190, C6208, (1) 24 mm.; 80.200, C6208, (11) 19–56 mm.; 82.69, C6303, (24) 33.5–57.5 mm.; 83.77, C6303, (716) 33.5–61 mm.; 83.90, C6303, (142) 33–51 mm.; 84.67, C6303, (11) 40–50 mm.; 84.70, C6303, (1) 44 mm.; 84.92, B6303, (4) 29.5–57 mm.; 86.92, C6303, (11) 33.5–52.5 mm.; 87.80, C6303, (6) 36–47.5 mm.; 90.48a, H6105, (1) 42 mm.; 90.70, H6204, (2) 45–48 mm.; 90.80, C6208, (5) 23–32 mm.; 90.110, C6303, (1) 25.5 mm.; 90.120, H6204, (4) 18–49 mm.; 90.120, C6208, (64) 19–26.5 mm.; 90.150, C6208, (73) 15–27 mm.; 90.160, H6204, (5) 19–50 mm.; 90.160, C6208, (6) 48–53 mm.; 90.180, B6203, (1) 21 mm.; 90.180, H6204, (6) 29–57 mm.; 90.180, C6208, (1) 21 mm.; 90.200, H6204, (9) 15–53 mm.; 91.39a, C6208, (1) 52 mm.; 92.115, B6303, (1) 24 mm.; 97.40, C6303, (7) 38–51 mm.; 97.65, C6303, (85) 28.5–44 mm.; 100.60, H6204, (9) 38–51 mm.; 100.65, C6303, (944) 20–52 mm.; 100.80, H6204, (2) 36–40 mm.; 100.90, H6204, (1) 38 mm.; 100.100, H6204, (9) 22.5–59 mm.; 100.120, H6204, (3) 47–50 mm.; 100.140, H6204, (9) 20–29 mm.; 100.160, H6204, (2) 21–39 mm.; 108.63, C6303, (118) 29.5–46.5 mm.;

110.40, H6204, (1) 40 mm.; 110.120, H6204, (3) 24–30 mm.; 110.160, H6204, (13) 17–54 mm.; 120.70, H6204, (8) 30–41 mm.; 120.80, H6204, (9) 26.5–46 mm.; 120.90, H6204, (9) 25–39 mm.; 123.45, B6212, (6) 24–29.5 mm.; 127.45, B6212, (1) 22.5 mm.; 133.35, B6212, (1) 20.5 mm.; 140.35, B6212, (1) 32.5 mm.

104. *Notoscopelus resplendens* Richardson.

Figure 23D.

66.100, C6208, (3) 29–37 mm.; 80.80, H6204, (1) 58 mm.; 80.160, C6208, (2) 27 mm.; 80.170, C6208, (1) 31 mm.; 80.190, C6208, (3) 27.5–31 mm.; 86.92, C6303, (3) 56.2–60.5 mm.; 90.120, C6208, (15) 26–31 mm.; 90.140, C6208, (1) 27 mm.; 90.150, C6208, (12) 22.5–32.5 mm.; 90.160, H6204, (1) 64 mm.; 90.200, H6204, (1) 15 mm.; 100.65, C6303, (18) 43–64 mm.; 100.100, H6204, (1) 34.5 mm.; 100.120, H6204, (1) 70 mm.; 100.160, H6204, (1) 26 mm.; 108.63, C6303, (2) 44–60 mm.; 110.120, H6204, (1) 61 mm.; 120.90, H6204, (1) 67 mm.

105. Myctophidae, unidentified.

60.55, C6280, (1) discarded at sea; 70.80–5N, B6203, (1) adult; 70.200, H6204, (1) juvenile; 80.80, C6303, (2) discarded at sea; 80.90, B6203, (4) adults; 90.140, C6208, (2) juveniles; 90.150, C6208, (1) adult; 90.160, H6204, (2) juveniles; 90.200, H6204, (2) larvae, may be *Lepidophanes pyrsobolus*.

These specimens are badly damaged or otherwise unidentifiable and probably represent several species.

PARALEPIDIDAE

106. *Sudis atrox* Rofen.

Figures 24 and 25A.

80.160, C6208, (1) 21.5 mm.

The genus *Sudis* of the monotypic subfamily Sudinae was for many years known only from the eastern Atlantic off Madeira and the Mediterranean as *Sudis hyalina* Rafinesque. The larval stages of this species were described and illustrated by Sanzo (1918). A review of the genus *Sudis* was presented by Harry (1951 : 33–35). A new species from the eastern Pacific, *Sudis atrox*, was recently described by Rofen (1963 : 5, fig.1). *S. atrox* was based on a 75-mm. SL holotype and “35 identifiable remains” taken from stomach contents of *Alepisaurus* and *Parethunnus sibi* at two stations several hundred kilometers west of Baja California. Fourteen specimens of *S. atrox*, 3.4 mm. Notochord Length to 12.5 mm. SL had been sorted from 13 stations of Norpac Expedition between Hawaii and the American mainland (E.H. Ahlstrom, personal communication).



FIGURE 24.—*Sudis atrox*. 21.5 mm. SL station 80.160, C6208.

107. *Lestidium ringens* (Jordan and Gilbert).

Figure 25A.

60.80, C6208, (1) 60 mm.; 60.120, B6203, (1) 72 mm.; 70.80, B6203, (1) 39 mm.; 80.80, H6204, (1) 53 mm.; 80.90, H6204, (2) 20–71 mm.; 80.100, H6204, (1) 78 mm.; 90.90, C6203, (35) 42–64 mm.; 90.120, H6204, (1) 28 mm.; 100.40, H6204, (1) 150 mm.

The 35 specimens taken in the *Cobb* pelagic trawl at station 90.90 indicate that this species may occur in large schools at least in certain areas. It has been identified from a large number of routine CalCOFI plankton-tow stations, but only one or a few specimens had been taken in a single tow. *Lestidium elongatum* Ege is undoubtedly a junior synonym of this species (E. H. Ahlstrom and R. R. Rofen, personal communications). The specimen reported as *Macroparalepis* sp. by Harry (1953: 186, fig. 5) is a young stage of *L. ringens*.

108. *Notolepis rissoi* (Bonaparte).

Figure 25A.

70.200, H6204, (1) 59 mm.; 80.160, C6208, (2) ca. 37–ca. 65 mm.; 80.200, C6208, (1) ca. 30 mm.; 90.120, C6208, (10) 32–49 mm.

This species has generally been designated under the name of *Notolepis coruscans* (Jordan and Gilbert) (R. R. Rofen, personal communication). Our relatively small and mostly damaged specimens have lower numbers of anal fin rays (a maximum of 26 or 27) than other eastern Pacific specimens that have been reported (A. 29 to 33) (Harry, 1953: 210).

109. *Macroparalepis macrurus* Ege.

Figure 25A.

70.200, H6204, (1) 41.5 mm.; 80.160, C6208, (1) ca. 59 mm.; 80.170, C6208, (1) ca. 73 mm.; 80.180, H6204, (1) 135 mm.; 80.200, C6208, (4) ca. 42–ca. 74 mm.; 90.80, C6208, (1) ca. 70 mm.; 90.100, C6208, (1) ca. 62 mm.; 90.120, C6208, (13) 67–77 mm.; 90.140, C6208, (1) ca. 72 mm.; 90.150, C6208, (73) ca. 61–82 mm.; 90.200, H6204, (1) ca. 27 mm.

This species is more widespread in the eastern Pacific, and perhaps more gregarious, than previously shown. The larvae have been taken in offshore plankton-net collections, but most catches had only one or two individuals. Most of the records reported by Ege (1957: 94–95) are of single specimens; the maximum at one station was nine. The 73 specimens taken at station 90.150 in September by the *Cobb* pelagic trawl indicate that the species is at times locally abundant.

The above records extend the known range of the species. Previously Ege (1957: 68) had recorded it from northeast of the Galapagos Islands. Harry (1953: 231) placed this species in the genus *Stemnosudis* Harry, but our specimens, and apparently those of Ege, possess characters more like those of *Macroparalepis*. The 135-mm. specimen, one of the largest specimens of the species to be recorded, has the anterior lateral line scales only slightly higher than long (1.17X), the nostrils well in advance of a vertical line through the posterior end of the maxillary, D. 8, A. 38, vertebrae 96 total and 33 prehaemal, and the anterior peritoneal pigment spots coalesced (about 14 were present).

SCOPELARCHIDAE

110. *Benthalbella dentata* (Chapman).

Figure 25B.

83.90, C6303, (1) 43.5 mm.; 83.77, C6303, (1) 42 mm.; 87.80, C6303, (1) 118 mm.; 100.65, C6303, (1) 200 mm.; 108.63, C6303, (1) 167 mm.

Chapman (1939: 530) described this species in the new genus he proposed, *Neoscopelarchoides*. Marshall (1955: 314) used this generic name rather than *Benthalbella* Zugmayer 1911. These two generic names, however, are synonymous, and under the current International Rules of Zoological Nomenclature, *Benthalbella* has priority (E. H. Ahlstrom, personal communication).



FIGURE 25.—Locations of capture of: A, *Sudis atrox*, *Lestidium ringens*, *Notolepis rissoi*, *Macroparalepis macrurus*. B, *Benthallbella dentata*, *Scopelarchus nicholsi*, *Scopelarchus guentheri*, *Scopelarchus sp.*, *Evermannella indica*. C, *Anotopterus pharao*, *Bathyleptus lisae*, *Ditropichthys sp.*, *Cololabis saira*. D, *Serrivomer sector*, *Nemichthys scolopaceus*.

111. *Scopelarchus nicholsi* (Parr).

Figure 25B.

120.50, H6204, (1) 42.5 mm.; 120.80, H6204, (1) 62 mm.

112. *Scopelarchus guentheri* Alcock.

Figure 25B.

108.63, C6303, (1) 50 mm.; 110.35, C6303, (1) 46 mm.

113. *Scopelarchus* sp.

Figure 25B.

84.70, C6303, (1) 28 mm.; 90.47, C6208, (1) 26 mm.;
97.40, C6303, (2) 37 mm.; 110.46, C6303, (1) 28 mm.

There is a very good possibility that these specimens represent an undescribed species.

EVERMANNELLIDAE

114. *Evermannella indica* Brauer.

Figure 25B.

120.90, H6204, (1) 55.5 mm.

ANOPTERIDAE

115. *Anopterus pharao* Zugmayer.

Figure 25C.

60.180, H6204, (1) 173 mm.; 90.120, H6204, (1) 80.5 mm.; 90.160, H6204, (1) 59 mm.; 100.140, H6204, (1) ca. 179 mm.; 100.160, H6204, (2) 96–103 mm.

APODES

DERICHTHYIDAE

116. *Derichthys serpentinus* Gill.

Figure 26A.

108.63, C6303, (1) 200 mm.

This specimen and one in the collections of Scripps Institution of Oceanography from about 215 km. (135 miles) southward of Punta Eugenia are the first records of this species from this area.

CYEMIDAE

117. *Cyema atrum* Günther.

Figure 26A.

60.70, H6204, (1) 101+ mm.; 60.100, H6204, (1) 145+ mm.; 60.140, H6204, (1) 126+ mm.; 60.180, H6204, (1) 131+ mm.; 70.200, H6204, (1) 106+ mm.; 80.100, H6204, (1) 96+ mm.; 83.90, C6203, (1) 50 mm.; 90.120, H6204, (1) 107+ mm.; 100.60, H6204, (1) 115+ mm.; 100.80, H6204, (1) 100+ mm.; 100.160, H6204, (3) 125–134+ mm.; 110.160, H6204, (1) 147+ mm.; 120.50, H6204, (1) 110+ mm.

SERRIVOMERIDAE

118. *Serrivomer sector* Garman.

Figure 25D.

60.60, H6204, (1) 557+ mm.; 83.77, C6303, (1) 582 mm.; 84.70, C6303, (1) 461 mm.; 86.92, C6303, (15) 312–645 mm.; 87.80, C6303, (4) 500–541 mm.; 87.90, C6303, (2) 436–537 mm.; 100.60, H6204, (1) 461+ mm.; 100.65, C6303, (1) 386 mm.; 108.63, C6303, (2) 532–574 mm.; 110.120, H6204, (1) 490+ mm.; 120.70, H6204, (1) 532+ mm.

NEMICHTHYIDAE

119. *Avocettina bowersi* (Garman).

Figure 26A.

60.100, H6204, (1) 551 mm.; 84.67, C6303, (1) 320 mm.; 86.92, C6303, (8) 395–675 mm.; 87.80, C6303, (5) 319–550 mm.; 87.90, C6303, (2) 460–462 mm.; 90.110, C6303, (1) 229 mm.; 90.160, H6204, (1) 445+ mm.; 93.100, C6303, (2) 395–485 mm.; 100.100, H6204, (1) 612 mm.; 110.120, H6204, (1) 541 mm.; 120.70, H6204, (1) 532 mm.; 120.80, H6204, (1) 499+ mm.; 123.50, B6203, (5) ca. 364–510 mm.

120. *Nemichthys scolopaceus* Richardson.

Figure 25D.

60.140, H6204, (1) 453 mm.; 60.160, B6203, (1) 477 mm.; 60.200, H6204, (1) 621 mm.; 70.80b, B6203, (1) 545+ mm.; 70.80, C6208, (1) 500+ mm.; 73.200, B6203, (1) 392 mm.; 80.90, H6204, (1) 561 mm.; 80.160, C6208, (5) 108–252 mm.; 90.70, H6204, (1) 273 mm.; 90.140, H6204, (1) 442 mm.; 90.160, C6208, (17) 118–220 mm.; 97.40, C6303, (2) 300–350 mm.; 100.40, C6303, (1) 406 mm.; 100.65, C6303, (1) 525 mm.; 120.45, H6204, (1) 761 mm.; 120.60, H6204, (1) 607 mm.; 123.50, B6203, (1) 761 mm.

121. Nemichthyidae, unidentified.

120.70, H6204, (1) 327+ mm.

This specimen is badly damaged.

CONGRIDAE

122. *Ariosoma gilberti* (Ogilby).

Figure 26A.

137.35, B6212, (3) 135–223 mm.; 140.35, B6212, (1) 145 mm.; 147.30, B6212, (1) 155 mm.

123. Congridae, unidentified.

133.35, B6212, (1) 144 mm.

This *Congrina* "like" specimen is damaged.

OPHICHTHYIDAE

124. Ophichthyidae, unidentified.

137.35, B6212, (1) 71 mm.; 143.30, B6212, (1) 121 mm.

These leptocephali have not been otherwise identified.

SYNENTOGNATHI

SCOMBERESOCIDAE

125. *Cololabis saira* (Brevoort).

Figure 25C.

60.200, B6203, (1) 66 mm.; 70.200, H6204, (1) 57 mm.;
80.100, B6203, (1) 69 mm.; 84.92, B6303, (1) 31.5 mm.;
127.45, B6212, (1) 25 mm.

ANACANTHINI

MORIDAE

126. *Melanonus zugmayeri* Norman?

Figure 26B.

60.90, H6204, (1) 112 mm.; 60.160, H6204, (1) 120 mm.;
86.92, C6303, (1) 214 mm.; 87.80, C6303, (1) 115 mm.;
108.63, C6303, (2) 148-209 mm.

These specimens are tentatively identified as this species pending further study (D. M. Cohen, personal communication).

GADIDAE

127. *Merluccius products* (Ayres).

Figure 26B.

60.55, C6208, (7) 179-414 mm.; 65.54, C6208, (1) 265 mm.; 70.51, C6208, (186) 150-244 mm.; 80.55, H6204, (1) 166 mm.; 80.60, C6208, (4) 375-415 mm.; 80.70, H6204, (1) 10.5 mm.; 80.80, H6204, (2) 9-10 mm.; 80.90, H6204, (9) 7.5-10 mm.; 80.100, H6204, (12) 6-11 mm.; 82.45, C6208, (38) 80-220 mm.; 82.69, C6303, (38) 285-518 mm.; 83.70a, B6303, (1) 471 mm.; 83.70, C6303, (9) 327-505 mm.; 83.77, C6303, (5) 299-361 mm.; 84.67, C6303, (4) 396-504 mm.; 84.70, C6303, (2) 374-478 mm.; 84.71, C6303, (1) 492 mm.; 90.45a, H6105, (1) juvenile, damaged; 90.47, C6208, (3) 192-345 mm.; 90.48a, H6105, (3) 16-25.5 mm.; 90.48b, H6105, (33) 17-31.5 mm.; 90.48c, H6105, (6) 20.5-36 mm.; 94.28b, C6208, (1) 430 mm.; 94.30, C6208, (7) 162-420 mm.; 94.32b, B6204, (1) 17 mm.; 95.31d, B6204, (3) 19.5-36.5 mm.; 97.40, C6303, (29) 327-688 mm.; 99.31, C6208, (2) 192-370 mm.; 100.40, H6204, (4) 20-22 mm.; 100.40, C6203, (1) 398 mm.; 110.35, H6204, (1) 23 mm.; 110.35, C6303, (131) 244-577 mm.; 110.36, C6303, (3) 376-496 mm.; 111.36a, C6303, (495) ca. 258-598 mm.; 111.36b, C6303, (ca. 300) ca. 239-515 mm.; 111.37a, C6303, (65) 282-479 mm.; 113.34a, C6303, (8) 20.5-392 mm.; 120.45, H6204, (2) 19-23 mm.; 120.45, B6212, (1) 266 mm.; 120.50, H6204, (2) 31-34.5 mm.; 120.60, H6204, (1) 23.5 mm.; 147.30, B6212, (8) 105-150 mm.

MACROURIDAE

128. *Coryphaenoides acrolepis* (Bean)?

Figure 26B.

60.60, H6204, (1) 515 mm.

The species of this genus in this area are confused, and this identification must be tentative until the problems are resolved.

129. Macrouridae, unidentified.

86.92, C6303, (2) 333-347 mm.

These two specimens from about 305 km. (190 miles) SW. of Point Conception, Calif., represent an undescribed genus and species of bathypelagic macrouroid (C. L. Hubbs, personal communication).

130. Macrouridae, unidentified.

100.40, H6204, (1) 32 mm.

This specimen is too small to identify without comparative material.

LOPHOBRANCHII

SYNGNATHIDAE

131. *Syngnathus arcta* (Jenkins and Evermann).

90.45, H6105, (1) 166 mm.; 95.31b, B6204, (1) 72 mm.

ALLOTRIognathi

TRACHIPTERIDAE

132. *Desmodema polystictum* (Ogilby).

Figure 26C.

89.90, C6303, (1) 614 mm.; 90.160, C6208, (1) 1,106 mm.; 100.80, H6204, (1) 455+ mm.

133. *Trachipterus t. altivelis* Kner.

Figure 26C.

60.90, C6208, (2) 49.5-1,435 mm.; 70.60, C6208, (1) 1,014 mm.; 80.52, C6208, (2) 177-297 mm.; 82.45, C6208, (2) 187-275 mm.; 85.68, C6303, (1) 133 mm.; 86.92, C6303, (1) 605 mm.; 90.47, C6208, (1) 1,000 mm.; 93.29, C6208, (1) 445 mm.

LOPHOTIDAE

134. *Lophotus* sp.

Figure 26C.

80.170, C6208, (1) 46.5 mm.

This specimen is too small to allow specific identification (J. E. Fitch, personal communication).

BERYCOMORPHI

MELAMPHAIDAE

135. *Scopelogadus mizolepis bispinosus* (Gilbert).

Figure 26D.

60.60, H6204, (2) 24-72 mm.; 60.80, C6208, (1) 33 mm.; 60.90, H6204, (3) 18-51 mm.; 60.100, H6204, (2) 13-75



FIGURE 26.—Locations of capture of: A, *Derichthys serpentinus*, *Cyema atrum*, *Avocettina bowersi*, *Ariosoma gilberti*. B, *Melanonus zugmayeri*?, *Merluccius productus*, *Coryphaenoides acrolepis*?, C, *Desmodema polystictum*, *Trachipterus trachipterus altivelis*, *Lophotus* sp. D, *Scopelogadus mizolepis bispinosus*, *Poromitra crassiceps*, *Poromitra* sp., *Scopeloberyx robustus*.

mm.; 60.120, H6204, (10) 63-75 mm.; 60.140, H6204, (1) 67 mm.; 60.160, H6204, (2) 64-75 mm.; 60.180, H6204, (2) 30-43 mm.; 60.200, B6203, (1) 53 mm.; 70.200, H6204, (1) 28 mm.; 80.55, H6204, (1) 63 mm.; 80.60, H6204, (2) 18-68 mm.; 80.80, H6204, (7) 45-60 mm.; 80.90, B6203, (2) 41-47 mm.; 80.90, H6204, (3) 65-79 mm.; 86.92, C6303, (13) 25-90 mm.; 87.90, C6303, (8) 29-90 mm.; 90.45a, H6105, (1) 47 mm.; 90.70, H6204, (11) 45-68 mm.; 90.70, C6208, (3) 61-70 mm.; 90.110, B6203, (1) 70 mm.; 90.140, H6204, (2) 66-74 mm.; 90.160, H6204, (2) 21-44 mm.; 90.160, C6208, (2) 56-58 mm.; 93.100, C6303, (1) 35 mm.; 94.32a, B6204, (2) 56-58 mm.; 97.40, C6303, (12) 36-45 mm.; 100.40, H6204, (2) 54-55 mm.; 100.40, C6303, (1) 49 mm.; 100.60, H6204, (5) 56-82 mm.; 100.65, C6303, (17) 43-76 mm.; 100.80, H6204, (4) 20-52 mm.; 100.90, H6204, (5) 34-74 mm.; 100.100, H6204, (3) 35-54 mm.; 100.120, H6204, (1) 56 mm.; 100.140, H6204, (1) 53 mm.; 100.160, H6204, (3) 25-64 mm.; 108.63, C6303, (26) 45-87 mm.; 110.35, H6204, (1) 62 mm.; 110.35, C6303, (2) 30-43 mm.; 110.40, H6204, (1) 45 mm.; 110.50, B6203, (2) 55.5 mm.; 110.120, H6204, (3) 18-79 mm.; 110.160, H6204, (5) 10-83 mm.; 120.45, H6204, (1) 54 mm.; 120.60, H6204, (1) 55 mm.; 120.70, H6204, (6) 45-62 mm.; 120.80, H6204, (3) 28-51 mm.; 120.90, H6204, (3) 46-83 mm.; 137.50, B6203, (5) 26-58 mm.

This species, previously known as *Melamphaes bispinosus* or *Scopelogadus bispinosus*, has recently been shown to be a subspecies of *Scopelogadus mizolepis* (Günther) by Ebeling (1963:19).

136. *Poromitra crassiceps* (Günther).

Figure 26D.

60.60, H6204, (1) 127 mm.; 60.100, H6204, (1) 117 mm.; 60.140, H6204, (1) 30 mm.; 60.180, H6204, (2) 22-45.5 mm.; 80.90, H6204, (1) 24 mm.; 90.48b, H6105, (1) 25 mm.; 90.160, C6208, (2) 91-96 mm.; 120.45, H6204, (1) 89 mm.; 120.90, H6204, (2) 92-97 mm.

This species has been listed under the name of its junior synonym, *Poromitra cristiceps* (Gilbert).

137. *Poromitra* sp.

Figure 26D.

70.200, H6204, (2) 51-64 mm.; 100.100, H6204, (1) 70 mm.; 120.70, H6204, (1) 75 mm.

These specimens, with relatively small eyes and a low number of dorsal fin rays (III, 10 or 11) are representative of a new species. This was called to our attention by A. W. Ebeling (personal communication), who is preparing a detailed description for publication.

138. *Scopeloberyx robustus* (Günther).

Figure 26D.

60.180, H6204, (1) 31 mm.; 70.200, H6204, (2) 18-21 mm.; 80.180, C6208, (1) 12 mm.; 90.200, H6204, (2) 31.5-32 mm.; 100.60, H6204, (1) 71.5 mm.; 100.160, H6204, (6)

18-32 mm.; 120.45, H6204, (3) 57-59 mm.; 120.70, H6204, (1) 60 mm.

This species has generally been known in this area as *Scopeloberyx nycterinus* (Gilbert). The synonymy of *S. nycterinus* with *S. robustus* has recently been determined by A. W. Ebeling (personal communication).

139. *Melamphaes acanthomus* Ebeling.

Figure 27A.

90.45a, H6105, (2) 83-92 mm.; 100.65, C6303, (1) 81 mm.

140. *Melamphaes indicus* Ebeling.

Figure 27A.

90.160, H6204, (1) 35.5 mm.

This record extends the known range of this species eastward from west of the Hawaiian Islands, as delimited by Ebeling (1962, fig. 47).

141. *Melamphaes laeviceps* Ebeling.

Figure 27B.

60.200a, B6203, (2) 28-29 mm.; 60.200, H6204, (1) 27 mm.; 73.200, B6203, (4) 24-29 mm.; 80.200, C6208, (3) 27-28 mm.; 87.200, B6203, (1) 27 mm.; 90.150, C6208, (1) 26 mm.; 90.160, H6204, (1) 28 mm.; 100.140, H6204, (1) 28 mm.

This species previously has only been reported from the tropical eastern and central Pacific (Ebeling, 1962, fig. 53).

142. *Melamphaes longivelis* Parr.

Figure 27B.

90.120, H6204, (1) 33 mm.

This specimen represents a range extension for the species of about 260 km. (160 miles) northeast from that shown by Ebeling (1962:77, not fig. 44).

143. *Melamphaes lugubris* Gilbert.

Figure 27B.

60.60, H6204, (2) 30-84 mm.; 60.80, H6204, (1) 55 mm.; 60.80, C6208, (1) 19 mm.; 60.90, H6204, (3) 22-79 mm.; 60.120, B6203, (2) 38 mm.; 70.80b, B6203, (1) 37 mm.; 80.55, H6204, (3) 38-41 mm.; 80.60, H6204, (1) 44 mm.; 80.75, B6303, (1) 17 mm.; 80.80, H6204, (3) all ca. 40 mm.; 80.90, H6204, (5) 37-43 mm.; 80.100, B6203, (1) 37 mm.; 80.100, H6204, (2) 20-22 mm.; 80.110, B6203, (1) 13 mm.; 83.77, C6303, (1) 22 mm.; 84.92, B6303, (7) 36-39 mm.; 86.92, C6303, (5) 36-52 mm.; 87.80, C6303, (4) 35-38 mm.; 90.45a, H6105, (4) 51-77 mm.; 90.70, H6204, (2) 40-43 mm.; 90.70, C6208, (7) 25.5-50 mm.; 97.40, C6303, (7) 31-36 mm.; 97.50, B6203, (1) 38 mm.; 100.60, H6204, (1) 21 mm.; 100.65, C6303, (1) 38 mm.; 108.63, C6303, (2) 32-37 mm.

144. *Melamphaes macrocephalus* Parr.

Figure 27A.

120.90, H6204, (1) 116 mm.

145. *Melamphaes parvus* Ebeling.

Figure 27A.

60.120, B6203, (1) 25.5 mm.; 60.120, H6204, (2) 35–37.5 mm.; 60.140, H6204, (4) 36–45 mm.; 60.160, B6203, (3) 36–48 mm.; 60.180, H6204, (1) 27 mm.; 80.80, H6204, (3) 37–38 mm.; 80.90, B6203, (1) 36 mm.; 80.90, H6204, (1) 45 mm.; 80.200, C6208, (1) 18 mm.; 82.69, C6303, (2) 33–38 mm.; 84.92, B6303, (3) 43–47 mm.; 86.92, C6303, (5) 33–44 mm.; 87.80, C6303, (2) 38–43 mm.; 90.70, H6204, (2) ca. 38 mm.; 97.40, C6303, (1) 39 mm.; 100.60, H6204, (1) 41 mm.; 100.65, C6303, (20) 31–48 mm.; 100.160, H6204, (1) 18 mm.; 108.63, C6303, (6) 30–43 mm.

146. *Melamphaes suborbitalis* (Gill).

Figure 27B.

60.180, H6204, (1) 37 mm.

147. *Melamphaes* spp.

60.200, H6204, (1) 15 mm.; 80.80, H6204, (1) 17 mm.; 133.35, B6212, (1) 15 mm.

These damaged specimens probably represent more than one species.

ANOLOGASTERIDAE

148. *Anoplogaster cornuta* (Valenciennes).

Figure 27A.

80.200, C6208, (1) 94 mm.; 86.92, C6303, (7) 86–121 mm.; 87.80, C6303, (1) 94.5 mm.; 90.45a, H6105, (1) 94 mm.; 108.63, C6303, (1) 88 mm.

As pointed out by Grey (1955:293), *Caulolepis longidens* Gill is a junior synonym of this species.

PERCOMORPHI

CARISTIIDAE

149. *Caristius macropus* (Bellotti).

Figure 29A.

83.77, C6303, (1) 165 mm.

150. *Caristius maderensis* Maul?

Figures 28 and 29A.

108.63, C6303, (2) 148–160 mm.

The phylogenetic position of the Caristiidae and the true identity of these specimens are under study (C. L. Hubbs, personal communication).

SERRANIDAE

151. Serranidae, unidentified.

140.30, B6212, (6) 9–12 mm.

These specimens are too small to identify without comparative material.

CHEILODIPTERIDAE

152. *Howella brodiei* (Ogilby)?

Figure 29A.

60.120, B6203, (2) 52.5–70.5 mm.; 60.160, H6204, (1) 71 mm.; 80.80, H6204, (1) 29.5 mm.; 80.90, H6204, (3) 30.5–34 mm.; 100.80, H6204, (1) 36 mm.

The generic limits and the intrageneric components of *Howella* Ogilby 1898 are not definitive at this time. It apparently contains as synonyms the genera *Galeagra* Heller and Snodgrass 1903 and *Rhctogramma* Norman 1930; and, also apparently, these genera should be included in the family Cheilodipteridae (rather than Serranidae). The above specimens may represent a new species, but their characters are close to the descriptions given by Ogilby (1898:734) for *H. brodiei* from Lord Howe Island, and are similar to the accounts of this species from the Philippines given by Herre and Herald (1951:330) and from the North Atlantic Ocean by Koefoed (1952:5). Other specimens of *Howella* from the equatorial eastern Pacific that we have examined are specifically distinct from these tentatively designated as *H. brodiei*, and appear to be the *Galeagra pammelas* of Heller and Snodgrass. The monotypic *Sphyrnaenops bairdianus* Poey that has at times been placed in this complex apparently is generically distinct.

CARANGIDAE

153. *Trachurus symmetricus* (Ayres).

Figure 29A.

68.50, C6208, (1) 180 mm.; 70.80, C6208, (25) 64.5–503 mm.; 70.90, C6208, (1) 61 mm.; 70.100, C6208, (1) 60 mm.; 80.70, C6208, (1) 65 mm.; 80.80, C6208, (9) 28–69 mm.; 90.48b, H6105, (1) ca. 5 mm.; 90.49b, C6208, (12) 51–224 mm.; 90.80, C6208, (5) 23.5–64.5 mm.; 90.150, C6208, (1) 40 mm.; 91.39a, C6208, (1) 190 mm.; 91.39b, C6208, (3) 100–240 mm.; 93.26, C6208, (2) 100–125 mm.; 94.28b, C6208, (1) 435 mm.; 94.29b, C6208, (3) 335 mm.; 94.29c, C6208, (12) ca. 125 mm.; 99.31, C6208, size and number not recorded, discarded at sea; 113.34a, C6303, (1) 63 mm.; 120.50, H6204, (1) 23 mm.

Nine of the above records of jack mackerel were based on larvae or small juveniles. One of these was taken about 420 miles offshore (90.150, C6208). At station 70.80, C6208, about 185 km. (115 miles) offshore, a night surface drag with the Cobb trawl caught 1 small juvenile and 24 spawning and spent males and females.



FIGURE 27.—Locations of capture of: A, *Melamphaes acanthomus*, *Melamphaes indicus*, *Melamphaes macrocephalus*, *Melamphaes parvus*, *Anoplogaster cornuta*. B, *Melamphaes laeviceps*, *Melamphaes longivelis*, *Melamphaes lugubris*, *Melamphaes suborbitalis*. C, *Citharichthys sordidus*, *Citharichthys xanthostigma*, *Citharichthys stigmaeus*, *Bothus leopardinus*. D, *Microstomus pacificus*, *Glyptocephalus zachirus*, *Eopsetta jordani*.

CORYPHAENIDAE

154. *Coryphaena hippurus* Linnaeus.

147.30, B6212, (1) ca. 24 mm. damaged.

This specimen was taken about 80 km. (50 miles) offshore, south of Almejas Bay, Baja California.

STROMATEIDAE

155. *Cubiceps gracilis* (Lowe).

Figure 29B.

80.180, C6208, (2) 32.5–47 mm.; 80.190, C6208, (2) 31–40.5 mm.

Two recognized species of *Cubiceps* occur in the eastern Pacific, and *C. gracilis* appears to be the most suitable name to apply to the above specimens. The other species, *C. carinatus* Nichols and Murphy (1944:245), has fewer dorsal and anal fin softrays, fewer lateral line scales, and a more tropical distribution.

156. *Icichthys lockingtoni* Jordan and Gilbert.

Figure 29B.

60.80, H6204, (3) 11–15 mm.; 60.140, H6204, (2) 98–193 mm.; 70.80, B6203, (6) 20.5–27 mm.; 80.60, H6204, (1) 19 mm.; 80.90, B6203, (4) 20–46 mm.; 80.90, H6204, (13) 11–44.5 mm.; 80.100, B6203, (1) 19.5 mm.; 80.100, H6204, (2) 9–10.5 mm.; 80.120, B6203, (1) 14.5 mm.; 83.70a, B6303, (5) 27–42.5 mm.; 83.70c, B6303, (1) 32.5 mm.; 83.77, C6303, (1) 29.5 mm.; 90.45b, H6105, (1) 26 mm.; 90.48c, H6105, (1) 57.5 mm.; 90.80, C6208, (1) 40 mm.; 90.120, H6204, (1) 8 mm.; 94.29d, C6208, (3) 81–95 mm.; 100.65, C6303, (1) 39 mm.

157. *Palometa simillima* (Ayres).

Figure 29B.

80.52, C6208, (3) 51.5–61 mm.; 82.45, C6208, (1) 48 mm.; 93.26, C6208, (83) ca. 50–75 mm.; 94.28a, C6208, (2) small, size not recorded, discarded at sea; 94.28b, C6208, (4) ca. 50–75 mm.; 94.29b, C6208, (37) 78–147 mm.; 94.29c, C6208, (3) ca. 50 mm.; 99.31, C6208, (32) 85–165 mm.; 120.50, H6204, (7) 12–20 mm.

TETRAGONURIDAE

158. *Tetragonurus cuvieri* Risso.

Figure 29B.

100.65, C6303, (1) 51 mm.; 88.105a, B6303, (1) 37 mm.

When first seen in the cod end of the collapsible net, the 37-mm. specimen was alive within the cavity of a pyrosome. A few records of association of *T. atlanticus* Lowe and *T. cuvieri* with medusae were summarized by Mansueti (1963:59–60).

BRAMIDAE

159. *Brama japonica* Hilegendorf.

Figure 29C.

70.80, C6208, (3) 215–220 mm.; 70.200, H6204, (1) 15.5 mm.; 80.180, C6208, (1) 52.5 mm.

Two names previously used for pomfrets from the North Pacific, *B. brama* (Bonnaterre) and *B. raii* (Bloch), do not apply to this species (G. W. Mead, personal communication).

160. *Pteraclis velifera* (Pallas) ?

Figure 29C.

110.160, H6204, (1) 9.5 mm.

This small specimen can be identified only tentatively at this time (G. W. Mead, personal communication).

GEMPYLIDAE

161. *Gempylus serpens* Cuvier.

Figure 29C.

70.200, H6204, (1) 28 mm.; 80.180, C6208, (1) 52 mm.; 90.180, C6208, (1) 105 mm.

TRICHIURIDAE

162. *Lepidopus xantusi* Goode and Bean.

Figure 29C.

113.34a, C6303, (2) 230–249 mm.

SCOMBRIDAE

163. *Sarda lineolata* (Girard).

92.28, C6208, (3) 2–3 kg., discarded at sea, no length record taken; 93.26, C6208, (8) 2–4 kg., no length record; 93.28, C6208, (60) 340–490 mm.; 94.28b, C6208, (18) all ca. 300 mm.; 94.29b, C6208 (1) 335 mm.; 94.29c, C6208, (1) 4 kg., no length record; 94.30, C6208, (20) 2–4 kg., no length record; 95.30, C6208, (11) 2–4 kg., no length record; 113.34b, C6303, (1) adult, no size record.

These records are of adult fish taken close inshore and generally near the surface.

164. *Scomber japonicus* Houttuyn.

90.49b, C6208, (1) 288 mm.; 99.31, C6208, (16) 300–340 mm.

This species has also been referred to as *Scomber diego* Ayres, *Pneumatophorus japonicus*, and *Pneumatophorus diego*. This complex apparently also includes *Scomber colias* Gmelin of the Atlantic, and has previously been cited as such by various authors (B. B. Collette, personal communication).



FIGURE 28.—*Caristius maderensis*?, 160 mm. SL, station 108.63, C6303.

SCIAENIDAE

165. *Seriphus politus* Ayres.

93.25, C6208, (1) 175 mm.; 94.29c, C6208, (3) 165–186 mm.

166. *Roncador stearnsi* (Steindachner).

93.26, C6208, (131) ca. 150–175 mm.

SPHYRAENIDAE

167. *Sphyræna argentea* Girard.

93.26, C6208, (4) 260–325 mm.

CHIASMODONTIDAE

168. *Chiasmodon niger* Johnson.

120.90, H6204, (1) 47.5 mm.

This specimen was taken about 320 km. (200 miles) west of Punta Eugenia, Baja California.

169. *Kali* sp.

100.100, H6204, (1) 172 mm.

This specimen was taken about 480 km. (300 miles) west of Rosario Bay, Baja California. It cannot be specifically identified from current references, and the generic limits of *Kali* are confused—two genera appear to be included under this one name (D. M. Cohen, personal communi-

cation). Compared to specimens identified as *K. indica* (Lloyd) and *K. normani* (Parr) in the collections of Scripps Institution of Oceanography, this specimen is unique in having a reduced number of broad-based, short, blunt teeth in both jaws.

170. *Pseudoscopus scriptus* Lütken.

137.50, B6203, (1) 83.5 mm.

This specimen was taken about 160 km. (100 miles) west of Santa Maria Bay, Baja California. Parr (1933: 36–42) considered *P. scriptus* to consist of two subspecies and also described a new species, *P. altipinnis*. The above specimen is closer to the description Parr gave for *P. scriptus*, but it is possible that the two species are synonymous (R. J. Lavenberg, personal communication).

SCORPAENIDAE

171. *Sebastolobus alascanus* Bean.

Figure 29D.

60.60, H6204, (1) 26 mm.

172. *Sebastolobus altivelis* Gilbert.

Figure 29D.

60.120, H6204, (1) 40.5 mm.; 80.55, H6204, (5) 30.5–39.5 mm.; 80.60, B6203, (1) 31 mm.; 80.60, H6204, (1) 29.5 mm.; 80.70, C6208, (1) 14.5 mm.; 80.80, H6204, (2) 33 mm.; 80.90, H6204, (1) 36 mm.; 84.92, B6303, (2)



FIGURE 29.—Locations of capture of: A, *Caristius macropus*, *Caristius maderensis*?, *Howella brodiei*?, *Trachurus symmetricus*. B, *Cubiceps gracilis*, *Ichthyos lockingtoni*, *Palometa simillima*, *Tetragonurus cuvieri*. C, *Brama japonica*, *Pteraclis velifera*?, *Gempylus serpens*, *Lepidopus xantusi*. D, *Sebastolobus alascanus*, *Sebastolobus altivelis*, *Coryphopterus nicholsi*.

30–35 mm.; 90.32, H6204, (3) 34–47.5 mm.; 90.70, H6204, (1) 41.5 mm.; 90.70, C6208, (3) 13–15.5 mm.; 97.50, B6203, (3) 35.5–42 mm.; 100.40, H6204, (4) 39.5–45.5 mm.; 110.35, C6303, (4) 28–36.5 mm.

All these specimens are pelagic, prejuvenile specimens, taken from close inshore to 480 km. (300 miles) at sea.

173. *Sebastes diploproa* (Gilbert).

91.39b, C6208, (100+) ca. 31–41 mm.

174. *Sebastes saxicola* (Gilbert).

60.60, H6204, (5) 16–23 mm.

175. *Sebastes proriger* (Jordan and Gilbert) ?

60.60, H6204, (2) both 26.5 mm.

This identification is uncertain because of the small size of the specimens.

176. *Sebastes goodei* Eigenmann and Eigenmann.

68.50, C6208, (8) 197–231 mm.

177. *Sebastes jordani* (Gilbert).

94.30, C6208, (2) 188–192 mm.

178. *Sebastes* spp.

60.60, H6204, (2) 10–13 mm.; 60.70, H6204, (1) 5.5 mm.; 70.80–5N, B6203, (1) 15 mm.; 80.90, B6203, (1) 15.5 mm.; 90.48a, H6105, (1) 4.5 mm.; 90.48b, H6105, (1) 21.5 mm.

Specific identifications were not made because of the small size of these specimens.

ANOPILOMATIDAE

179. *Anoplopoma fimbria* (Pallas).

68.50, C6208, (1) 182 mm.

ZANIOLEPIDAE

180. *Zaniolepis frenata* Eigenmann?

90.32, B6203, (1) 22 mm.; 113.34a, C6303, (1) 39.5 mm.

These two small specimens may represent the sympatric *Z. latipinnis* Girard—adequate comparable material is not available to confirm our identification. The larger specimen appears, however, to be *Z. frenata*, because its third anal spine is shorter than the second.

AGONIDAE

181. Agonidae, unidentified.

90.48a, H6105, (1) 20.5 mm.; 90.48b, H6105, (2) 24.5–24.5 mm.; 90.60, B6203, (1) 19 mm.; 113.34a, C6303, (1) 15.5 mm.

Comparative material is not available that will allow identification of these small specimens (J. E. Fitch, personal communication).

GOBIIDAE

182. *Coryphopterus nicholsi* (Bean).

Figure 29D.

60.140, H6204, (2) 20–29 mm.; 80.90, H6204, (1) 15.5 mm.

These specimens, taken about 560 and 260 km. (350 and 160 miles) offshore, appear to be pelagic, oceanic, protracted prejuvenile stages of this species, which is generally known as an inshore, shallow-water, benthic inhabitant. Other specimens of this form have been taken in offshore waters at various times in CalCOFI routine, 140-m.-deep plankton tows.

183. Gobiidae, unidentified.

90.48a, H6105, (2) 7–8 mm.

BATRACHOIDIDAE

184. *Porichthys notatus* Girard.

94.29c, C6208, (2) 98–133 mm.

185. *Porichthys* sp.

65.54, C6208, (1) 125 mm.

This specimen was not identified to species and was discarded at sea.

BLENNIIDAE

186. *Hypsoblennius gentilis* (Girard).

123.45, B6212, (1) 15 mm.

ZOARCIDAE

187. *Melanostigma pammelas* Gilbert.

90.45a, H6105, (1) 108 mm.

HETEROSTOMATA

BOTHIDAE

188. *Citharichthys sordidus* (Girard).

Figure 27C.

60.60, C6208, (1) 25 mm.; 70.51, C6208, (6) 27–36 mm.; 70.60, C6208, (1) 32 mm.; 70.80–5N, B6203, (1) 27 mm.; 80.60, B6203, (1) 25.5 mm.; 80.60, C6208, (3) 28–32 mm.; 84.92, B6303, (1) 16 mm.

These are all pelagic larval and juvenile specimens taken from close inshore to about 290 km. (180 miles) at sea.

189. *Citharichthys xanhostigma* Gilbert.

Figure 27C.

113.34a, C6303, (a) all ca. 22 mm.

190. *Citharichthys stigmaeus* Jordan and Gilbert.

Figure 27C.

60.60, H6204, (2) 32.5–38.5 mm.; 60.60, C6208, (1) 26.5 mm.; 60.70, C6208, (1) 28.5 mm.; 60.80, C6208, (1) 32.5 mm.; 70.51, C6208, (6) 29.5–34 mm.; 80.60, C6208, (8) 24.5–30 mm.; 80.100, H6204, (2) 26.5–28 mm.; 83.70c, B6303, (1) 21 mm.; 83.90, C6303, (1) 22 mm.; 84.92, B6303, (1) 22 mm.; 90.45, H6105, (1) 29.5 mm.; 90.45a, H6105, (1) 29 mm.; 90.90, C6303, (14) 13–21.5 mm.; 90.48c, H6105, (2) 31 mm.; 97.40, C6303, (3) 23.5–26.5 mm.

These are all pelagic larval and juvenile specimens taken from close inshore to about 320 km. (200 miles) at sea.

191. *Citharichthys* sp.

67.50, C6208, (1) 150 mm.

This specimen was discarded at sea and not specifically identified.

192. *Bothus leopardinus* (Günther).

Figure 27C.

140.35, B6212, (2) 13–20 mm.

These specimens may be *B. constellatus* (Jordan), if *B. constellatus* is a distant species. Until distinction or synonymy can be established, we choose to use the earlier name.

PLEURONECTIDAE

193. *Microstomus pacificus* (Lockington).

Figure 27D.

70.51, C6208, (1) 28.5 mm.; 70.60, C6208, (1) 26.5 mm.; 80.70, H6204, (1) 21.5 mm.; 84.92, B6303, (1) 24 mm.; 97.40, C6303, (1) 30 mm.; 100.65, C6303, (2) 26–34 mm.; 100.160, H6204, (1) 42 mm.; 107.60, C6303, (1) 28.5 mm.

These larval specimens were taken from close inshore to about 840 km. (520 miles) off northern Baja California.

194. *Glyptocephalus zachirus* Lockington.

Figure 27D.

60.70, C6208, (1) 55.5 mm.; 60.90, C6208, (3) 36–62 mm.; 60.100, C6208, (1) 33 mm.; 70.60, C6208, (3) 39–45 mm.; 80.60, C6208, (1) 51 mm.

These larval specimens were taken about 55 to 315 km. (35 to 195 miles) offshore.

195. *Eopsetta jordani* (Lockington).

Figure 27D.

60.70, H6204, (1) 20 mm.

CYNOGLOSSIDAE

196. *Symphurus atricauda* (Jordan and Gilbert).

94.30, C6208, (1) 130 mm.

PLECTOGNATHI

MOLIDAE

197. *Mola mola* (Linnaeus).

94.28a, C6208, (13) "moderate size"; 94.28b, C6208, (4) 500–750 mm.; 94.29b, C6208, (3) all 380 mm.; 94.29c, C6208, 94.29d, C6208, (12) 378–1,460 mm.; (3) all ca. 450 mm.

PEDICULATI

ONEIRODIDAE

198. *Oneirodes eschrichtii* Lütken.

Figure 30.

80.80, H6204, (1) 52 mm.; 90.160, H6204, (1) 98 mm.; 100.140, H6204, (1) 25 mm.; 110.35, C6203, (1) 29 mm.; 120.45, H6204, (1) 26 mm.

These specimens fit the *O. eschrichtii* group as defined by Bertelsen (1951: 77–84), and further compare well with *O. eschrichtii* s.s. (R. H. Rosenblatt, personal communication).

199. *Oneirodes eschrichtii* Lütken?

Figure 30.

120.70, H6204, (2) 13.5–29.5 mm.

These two small specimens appear to represent this species (P. Struhsaker, personal communication).

200. *Oneirodes acanthias* (Gilbert)?

Figure 30.

123.50, B6203, (1) 24 mm.

This small specimen appears to represent this species (P. Struhsaker, personal communication).

201. *Chaenophryne parviconus* Regan and Trewavas.

Figure 30.

108.63, C6303, (1) 52 mm.

202. Oneirodidae, unidentified.

110.140, H6204, (1) 14 mm.

The identity of this free-living male is uncertain.

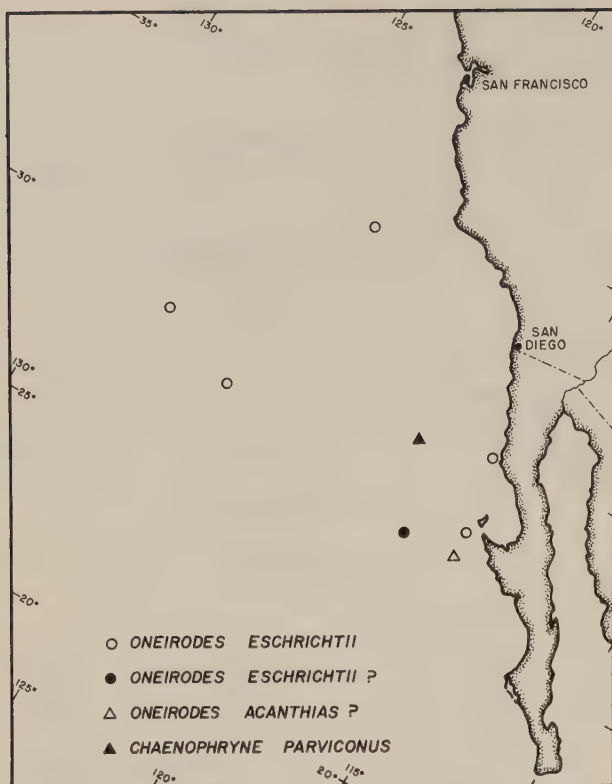


FIGURE 30.—Locations of capture of: *Oneirodes eschrichtii*, *Oneirodes eschrichtii?*, *Oneirodes acanthias?*, *Chaenophryne parviconus*.

ALPHABETICAL LIST OF FISHES

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COMPARISON OF TWO METHODS OF N-ETHYLCARBAZOLE CARBOHYDRATE ANALYSIS ¹

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Two currently used N-ethylcarbazole (NEC) methods for determining the amount of dissolved substances in sea water which respond to the NEC reagent and which will be referred to here as "carbohydrates," are the original one described by Erdman and Little ² and the modification described by Zein-Eldin and May (1958). It has been assumed by many investigators that those methods give comparable results when used to estimate the amount of carbohydrates in water. Recently, however, data obtained through both methods at the Bureau of Commercial Fisheries Biological Laboratory in Galveston, Tex., suggested that their corresponding estimates differ significantly. This difference prompted us to determine experimentally if the two methods yield the same results when used to analyze the carbohydrate content of aliquots from the same sample.

The original method described by Erdman and Little consists of adding the NEC reagent (1 g./l. of 36 N H₂SO₄) to the sample in one step, warming the mixture in a water bath, and then comparing color density with that of similarly treated arabinose (D-(-)-Arabinose) standards. This procedure will be called the "one-step" method. The method described by Zein-Eldin and May is the same as the above except that the NEC reagent is added in two steps. We will therefore refer to this procedure as the "two-step" method. Results of both procedures are based on the density of color

development when NEC reagent reacts with carbohydrates. Units are expressed in mg. equivalents of arabinose.

We compared the two methods by analyzing carbohydrate determinations obtained routinely from many samples with each procedure. The one-step method yielded significantly higher results (table 1).

TABLE 1.—Concentration of carbohydrates in samples of water collected from Galveston Island's East Lagoon during the period February–August, 1963

[Units are mg./l. of arabinose equivalents]

Date, 1963	Method		Date, 1963	Method	
	One-step	Two-step		One-step	Two-step
	Mg./l.	Mg./l.		Mg./l.	Mg./l.
Feb. 16.....	4.15	1.06	6-14	3.80	2.27
Feb. 19.....	4.00	.61	6-18	4.71	3.76
Mar. 1.....	3.80	1.98	6-21	3.92	2.32
Mar. 12.....	4.55	1.71	6-25	3.66	1.78
Mar. 15.....	4.35	2.61	6-28	4.64	3.25
Mar. 19.....	3.65	.78	7-2	5.69	3.90
Mar. 22.....	3.50	1.15	7-5	5.85	3.70
Mar. 26.....	3.20	.85	7-9	7.21	3.18
Mar. 29.....	2.55	.73	7-12	5.07	3.24
Apr. 2.....	3.11	1.86	7-16	4.28	3.03
Apr. 9.....	5.14	3.01	7-19	5.36	4.45
Apr. 23.....	3.17	2.33	7-23	4.28	2.58
May 8.....	4.06	1.98	7-26	6.50	3.48
May 10.....	2.43	2.15	7-30	4.71	3.15
May 14.....	3.91	2.36	8-2	5.07	2.94
May 17.....	3.94	2.02	8-7	5.07	2.18
May 21.....	3.28	2.13	8-9	7.85	3.03
May 24.....	2.31	2.24	8-13	4.57	2.67
May 28.....	3.03	1.71	8-16	5.00	3.51
May 31.....	3.60	2.25	8-20	4.07	2.70
June 4.....	4.13	2.70	8-21	2.55	2.47
June 7.....	3.33	1.99	8-22	3.60	2.36
June 11.....	4.58	2.63			

Upon investigating the reason for the differences noted between estimates secured by the two methods, we found that the color density resulting from interacting NEC and carbohydrates in natural waters varied only slightly with the method used. However, when the NEC reagent was added to standard or calibration samples that consisted of

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² Erdman, J. G. and A. B. Little, 1950. Analysis of marine coastal and estuarine waters, 50 pp. Multiple fellowship of Gulf Research and Development Co., Mellon Institute, Pittsburgh, Pa. (Unpublished.)

known concentrates of arabinose in distilled or saline water, the resulting color density varied with the method used. The variation was such

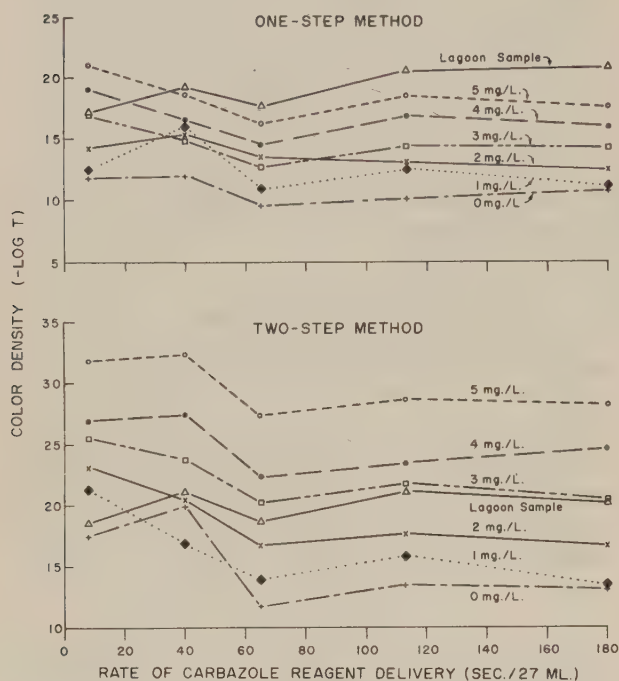


FIGURE 1.—Color density values obtained for six standard water samples and for one sample taken from Galveston Island's East Lagoon using two methods of carbohydrate analysis at five rates of reagent addition.

that estimates by the one-step method were higher than those obtained by the two-step method. We also found that the precision of estimates by either method is reduced if the reagent is added at a rate faster than about 27 ml.—the amount required by each procedure—per 65 seconds.

These conclusions become apparent from figure 1, which shows the raw data used to estimate the carbohydrate concentration in a water sample by both methods at various rates of reagent addition. If we consider only those portions of the curves from the 65-second addition rate and beyond, it can be seen that response of the carbohydrate in the sample to the NEC reagent corresponds to that of 6 to 7 mg./l. of arabinose by the one-step method, and 2.5 to 3 mg./l. by the two-step method. If the entire curves are considered, the sample estimates of carbohydrate concentration vary from about 0.3 to 7.0 mg./l. depending on the method used and also on the rate of reagent addition. The erratic results recorded when the reagent delivery rate was less than about 27 ml. per 65 seconds seem to be characteristic of both methods.

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RAPID METHOD FOR DETERMINING WATER CONTENT IN OYSTER TISSUE

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Medcof (1941) defined Condition Index (CI) as the ratio of the dry weight of the meat to the volume of the space between the valves $\times 1000$. To dry the meat, Engle (1958) used 72 hours exposure at 90° C. in a convection-type oven. This will reduce a 25 g. sample to constant weight; however, it is frequently desirable to avoid the 72-hour waiting period.

Korringa (1956) reported a method by which the water content of oyster meats could be determined volumetrically using toluene distillation. The homogenized sample was placed in a flask and covered with toluene. The flask was connected to a condenser fitted with a distillation trap and maintained at 100° C. for 1 hour. The volume of water collected was measured and converted to weight. The total time required was about 1 hour. We were unable to get the reproducible accuracy desired because of the tenacity with which small droplets of water adhered to the sides of the condenser and fittings. To overcome this problem we devised a gravimetric adaptation of Korringa's method which eliminates the condenser and its associated problems and in which the weight of water is determined directly. This adaptation is discussed below.

Figure 1 shows all major components of the apparatus. The function of the intake drying

tubes is to provide an atmosphere free of moisture. A 10 g. sample of homogenized oyster tissue is covered with toluene and heated to 100° C. for 45 minutes. The water vapor is collected in the tared outlet drying tubes. All tubes contain the drying agent, calcium chloride. Plastic check valves control direction of water vapor flow. The number of drying tubes needed can be determined by a trial run in which weights of the individual tubes are recorded. The last tube in direction of flow on both sides of the flask should not show a weight increase. In practice, once the proper number of tubes is determined, the tubes can be weighed as a unit. Suction should be applied very gently. With this method, we have been able to produce the same accuracy in 45 minutes that requires 72 hours in a conventional drying oven.

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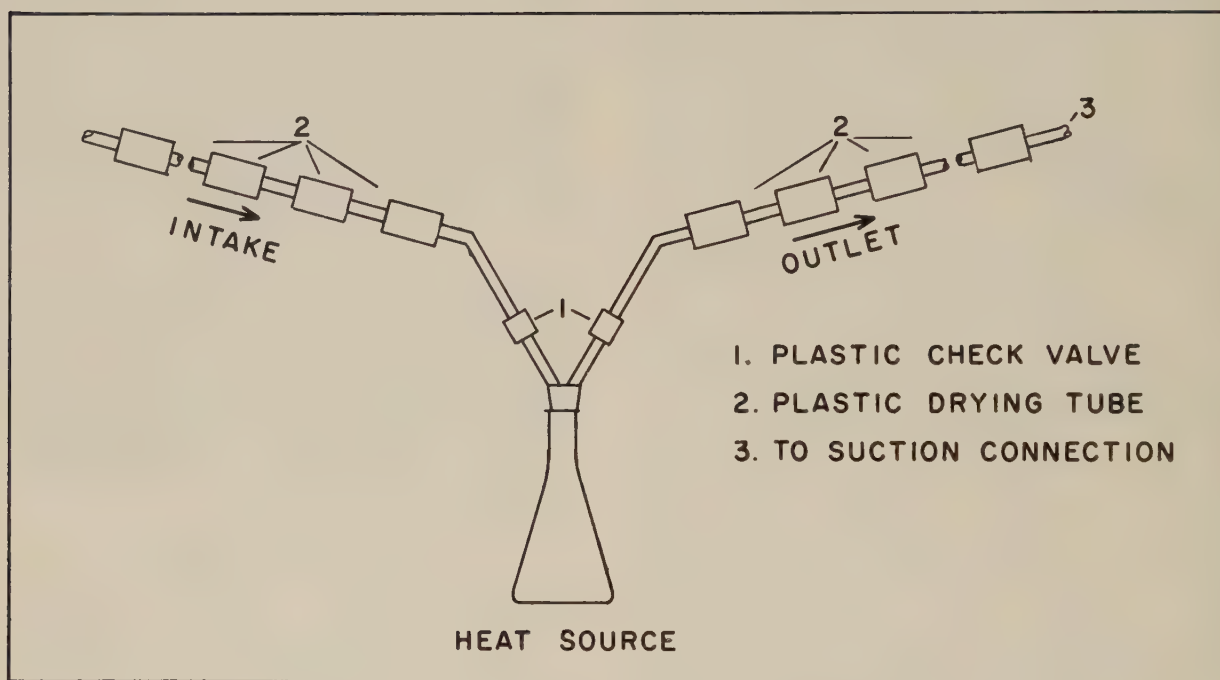


FIGURE 1.—Diagram of extraction apparatus.

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